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CANADA

DEPARTMENT OF
ENERGY, MINES AND RESOURCES
OTTAWA

MINERAL AND ENERGY RESOURCES PROGRAM

MINES BRANCH ACTIVITIES

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MINERAL AND ENERGY RESOURCES PROGRAM

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PREFACE

The goal of the Department of Energy, Mines and Resources Mineral and Energy Resources Program is to ensure the effective use of mineral and energy resources available in Canada for the present and future benefit of the nation.

The Mines Branch contributes to this program through three of its principal objectives as follows:

1. Ascertainment of Resource Potential

The branch participates by identifying metallic and non-metallic ore deposits by economic interest and by assessing fossil fuel resources.

2. Improvement of the Means of Discovery, Mining, Processing, Transportation and Use of the Mineral and Energy Resources Available to Canada

(1) Mining

The sub-objective comprises the development of mining technology important for exploiting Canadian resources through the following sub-activities:

1) Ground control research
2) Rock breakage-explosives research
3) Mine systems engineering
4) Environmental control research

(2) Minerals and Metals Technology

The branch aims to ensure the most effective conversion and use of minerals and metals in each of the following steps:

1) Beneficiation of new materials.
2) Processing of minerals for non-metallic uses.
3) Extraction and production of metals.
4) Fabrication of materials with specific composition and structure.
5) Investigation of the properties and uses of mineral and metallic materials.

(3) Energy

The branch undertakes the promotion of the fullest and best use of Canada's energy resources within the framework of a strong domestic industry by the following means:

1) Ensuring the efficient use of low-quality coal resources for electric power generation.
2) Ensuring the efficient use of coal resources for coke making.
3) Ensuring the use of large, low-grade petroleum resources.
4) Ensuring the efficient use of low-grade radioactive minerals.
5) Ensuring the efficient transportation of coal by pipelines, etc.
6) Minimizing the use of energy in metallurgical processes.

3. Protection and Improvement of the Environment

The branch's goal is to reduce air, water and land pollution arising from mining and metallurgical operations including the conversion of energy minerals. Activities are concerned with:

1) Prevention or abatement of pollution at the source.
2) Dispersion or disposal of effluents to tolerable levels as an intermediate measure.
3) Re-use of mineral and metallurgical residues and wastes.
4) Reduction of pollution and hazards in mines.

This report is a compilation of the various activity statements of the Mines Branch which have been developed using the following general pattern:

1. Objective (broad statement)
2. Background and Scope (more specific problems that require solving)
3. Description of Activity

4. Sub-Activity 1 (title of major sub-activity)
    (1) Situation
    (2) Planning assumptions
    (3) Relation to other Mines Branch studies
    (4) National need
    (5) Alternative national policies
    (6) Criteria
    (7) Preferred courses of action
    (8) Project titles and technical objectives
    (9) Projected costs and scheduling
    (10) Benefits
    (11) References

5. Sub-Activity 2 ------
6. Sub-Activity 3 ------
7. Three Year Financial Forecast of Sub-Activities

I trust that this report will be useful to the reader in identifying the contribution of the Mines Branch to the department's Mineral and Energy Resources Program.

John Convey

John Convey,
Director.

CONTENTS

Page

1. MINING ACTIVITY 1

OBJECTIVE 1
BACKGROUND AND SCOPE 1
DESCRIPTION OF MINING ACTIVITY 4

Sub.-A. 1 - Ground Control Research 4
Sub.-A. 2 - Rock Breakage - Explosives Research 9
Sub.-A. 3 - Mine Systems Engineering Research 18
Sub.-A. 4 - Environmental Control Research 25

MINING ACTIVITY: 3-YEAR FORECAST 35

2. MINERALS AND METALS TECHNOLOGY ACTIVITY POSITION PAPER (MAY, 1971) 38

Introduction 38
Background and Scope 38
National Need 39
Sub-Sub-Objectives 42-56

A - MINERAL PROCESSING DIVISION

Sub.-A. 1 - Improvements in Mineral and Metal Extraction Methods 57
Sub.-A. 2 - Utilization of Metallic Mineral Resources . . . 60
Sub.-A. 3 - Determining Changes in Minerals Technology and Utilization 65
Sub.-A. 4 - Conversion of Industrial Minerals 68
Sub.-A. 5 - Utilization of Industrial Minerals 75

B - EXTRACTION METALLURGY DIVISION

Sub.-A. 1 - Minerals and Metals Extraction 81
Sub.-A. 2 - Effective Use of Scarce Mineral and Metal Resources 89
Sub.-A. 3 - Ensuring an Awareness of Trends and Changes in Technology 93

Page

C - PHYSICAL METALLURGY DIVISION

Sub.-A. 1 - Processing of Metals and Alloys 97
Sub.-A. 2 - Utilization of Metals and Alloys 105

D - MINERAL SCIENCES DIVISION

OBJECTIVES 112

Sub.-Sub.-Obj. 1 - To Improve on Methods of Minerals and Metals Recovery. 112
Sub.-Sub.-Obj. 2 - To Ensure the Most Effective Use of Scarce Mineral and Metal Resources 120
Sub.-Sub.-Obj. 3 - To Ensure the Most Effective Conversion of Industrial Minerals to Useful Products
Sub.-Sub.-Obj. 4 - To Ensure the Efficient Processing of Metals and Alloys
Sub.-Sub.-Obj. 5 - To Ensure the Most Effective Utilization of Metal and Mineral Products 128
Sub.-Sub.-Obj. 6 - To Ensure a National Awareness of Trends and Changes in the Technology and Use of Minerals and Metals 129

E - MINERALS AND METALS TECHNOLOGY ACTIVITY: 3-YEAR FORECAST 135

3. ENERGY ACTIVITY 140

OBJECTIVE 140
BACKGROUND AND SCOPE 140

SUBACTIVITIES 145

A - FUELS RESEARCH CENTRE

Sub.-A. 1 - New Technology in Beneficiation of Low-Grade Petroleum Resources 145

1 - Hydrocarbon Processing and Catalysis Research . . . 145

Sub.-A. 2 - Evaluation of Fossil Fuels 151

1 - Service, Liaison and Consultation 151
2 - Evaluation of Petroleum and Natural Gas Resources . 154
3 - Solid Fuel Analytical Evaluation 158
4 - Dust Explosibility Research 162
5 - Evaluation of Coal Resources 167
6 - Evaluation of Peat Resources 171
7 - Evaluation of Fine Structures 175
8 - Research on Bituminous Substances 179

Page

B - METALS REDUCTION AND ENERGY CENTRE

Sub. - A. 1 - Coal Beneficiation Research 184
Sub. - A. 2 - Carbonization Research 190
Sub. - A. 3 - Pyrometallurgy Research 201
Sub. - A. 4 - Special Research 211

C - EXTRACTION METALLURGY DIVISION

Sub. - A. 1 - Pyrometallurgy Research Analysis 223
Sub. - A. 2 - Radioactive Mineral Resources 225

D - PHYSICAL METALLURGY DIVISION

Sub. - A. 1 - Pipeline Research 230

ENERGY ACTIVITY: 3-YEAR FORECAST 234

4. ENVIRONMENTAL IMPROVEMENT ACTIVITY 237

OBJECTIVE 237
BACKGROUND AND SCOPE 237

SUBACTIVITIES 240

Sub. - A. 1 - Characterization of Pollutants and Development of Pollution-Free Processes 240
Sub. - A. 2 - Dispersion and Disposal of Effluents 240

- 1 - Canadian Combustion Research Laboratory 240
- 2 - Extraction Metallurgy Division 254
- 3 - Mineral Sciences Division 260
- 4 - Metals Reduction and Energy Centre 266
- 5 - Physical Metallurgy Division 269

Sub. - A. 3 - Reduction of Pollution in Mines 275

- 1 - Research on Explosive Gases on Ignition and Explosion Phenomena 276
- 2 - Certification of Electrical Apparatus 281
- 3 - Certification of Diesel-Powered Mining Equipment . . 285

ENVIRONMENTAL IMPROVEMENT ACTIVITY: 3-YEAR FORECAST 290

5. SUMMARY OF MINES BRANCH ACTIVITIES: 3-YEAR FORECAST 1972/75 293

1. MINING ACTIVITY

OBJECTIVE

The objective of the mining program is to develop mining technology that is important for exploiting Canadian resources and to increase the efficiency of mining operations including those at great depths.

BACKGROUND AND SCOPE

Canadian mining, because it produces almost a complete range of metals and industrial minerals and because of its size, could become a world leader in the technology required for production, exploration, pollution abatement and conservation. In spite of consumption and production figures indicating that our natural resources will have an increasing scarcity value, the real world of experience shows that competition is becoming more severe. This fact, together with the reduction in average grade, the deepening of mining operations and the escalation of demands of labour, points to the increasing need for research that will continuously improve productivity, working conditions and conservation.

Mining can be characterized and differentiated from other industrial activities by the great and unpredictable changes in operating conditions. One result of this factor is that mining engineering has always had a much larger element of judgement and a smaller element of analysis than other areas of engineering. Today and in the future better predictability must be obtained to be able to use new scientific and industrial developments, such as those leading to improved operations control and continuous rather than batch production methods, that are necessary for automation. For success this work requires a multi-disciplined team effort, which is difficult for any organization, and particularly for both companies and universities to provide.

A dominant characteristic of mining companies is their concern for survival in the face of limited reserves for production. One consequence of this concern is the practice of spending as much as possible of operating profits on exploration. Another consequence is that production problems are viewed as transitory. Under these conditions the establishment of mining research facilities at the mines is not usually considered practical.

Universities can contribute the application of high quality brains but only on circumscribed subjects, their main concern being training students.

The solution to success in mining research is either for the entire industry to finance a central institute for research on the problems of all companies or for government enterprise to undertake the job.

The need for mining research is very much connected with the importance of conservation of our inheritance of non-renewable resources for optimum economic exploitation. The interest of the government in maximum recovery of orebodies is not necessarily realized by the free enterprise motive of maximizing profits.

Similarly, whereas mining companies do not have a bad record with regard to safety and health conditions, the dominant motive of maximizing profits does not ensure that over the long-term the necessary research work will be conducted to improve working conditions to an appropriate level. Also, although the constitutional jurisdiction for industrial health lies with the provinces, in the face of the absence of provincial research on mining conditions the federal government has an interest in solving technical problems in this area. Preservation of the surrounding environment also is a pale incentive compared to making profits.

Research programs, commensurate with the gross earnings of $1.5 billion per year accounted for by mining alone, would permit work to be done on all serious problems in the industry.

A division of projects has been made based on judgement between research that would lead to: (a) the advancement of new technology in mining operations, particularly those that will serve greater exploitation of mineral resources, (b) the improvement in working conditions, particularly with respect to safety and health, (c) the development of new mining systems, particularly those that will assist in preserving the environment, (d) the protection of the public from the hazards of explosives and other consequences of mining. Projects appropriate to those sub-objectives are selected on the basis of benefit/cost ratios, even though such criterion cannot always be made suitably quantitative.

The projects are grouped into the following sub-activities:

(1) Ground Control Research
(2) Rock Breakage - Explosives Research
(3) Mine Systems Engineering
(4) Environmental Control Research
(5) Advisory and Referral Services

Ground control research is concerned with fulfilling the objectives of advancing new technology in mining, improving working conditions and providing basic technology for new mining systems, particularly with regard to the requirement of minimizing damage to the external environment (such as subsidence, waste slides, and acid water runoff and radioactive dust clouds from tailings dams). 19 man-years and $336,000 will be allocated to this activity for the year 1971/72. The work is being done through the Elliot Lake Laboratory, the Western Office-Calgary and the Rock Mechanics Laboratory in Ottawa with a group consisting of engineers, geologists and a mathematician.

Considering the production commitments for western coal and the technical problems that remain to be overcome, it is becoming increasingly evident that the Western Office should be expanded so that it can contribute to the development of mining methods for extracting the coal from steeply dipping, thick seams. To undertake the research and development required for such assistance it would be necessary to recruit three experienced engineers for the Western Office together with support personnel at a cost of $120,000 per year. It is envisaged that such a team would usefully work on this problem for a period of five years.

Rock breakage - explosives research contributes to the objectives of advancing new technology, improving safety in mining operations and in the transportation of explosives, and developing new systems. 20 man-years and $304,000 will be allocated to this activity for the year 1971/72. The group working in this area consists of physicists, chemists and engineers. The work is done primarily at the Canadian Explosives Research Laboratory, but also at the Elliot Lake Laboratory and the Rock Mechanics Laboratory.

Some exploration has been conducted towards the establishment of a mining research laboratory in the Province of Quebec that would specialize in the area of rock breakage. The response has been very favourable from the universities, from industry and the indications are that the provincial government would welcome such a move. It would be possible to transfer a few of the existing staff to such a laboratory; however, a minimum of four new professionals plus supporting staff would be required at a cost of $160,000 per year.

Mine systems engineering research contributes to the objective of advancing new technology in mining by demonstrating the application of operations research and automation. 9 man-years and $226,000 will be allocated to this activity for the year 1971/72. The group working in this area consists of physicists and engineers. The work is being done at the Elliot Lake Laboratory and the Rock Mechanics Laboratory.

It has become increasingly evident over the past few years that the sensing of rock stability conditions and of ore grade beyond the face is becoming increasingly important. To be able to tackle such problems in the variety of mines in the Canadian industry, the minimum effective group to carry out both the laboratory and field activities would consist of two geophysicists and an engineer with supporting personnel at a cost of $100,000 per year.

DESCRIPTION OF MINING ACTIVITY

The goals and objectives of the sub-activities within the mining activity are:

(a) The advancement of new technology in mining operations, particularly those that will serve greater exploitation of mineral resources.
(b) The improvement in working conditions, particularly with respect to safety and health.
(c) The development of new mining systems, particularly those that will assist in preserving the environment.
(d) The protection of the public from the hazards of explosives and other consequences of mining.

Sub-Activity 1 - Ground Control Research

(1) Situation

In 1967, 340 million tons of ore and 200 million tons of waste (total 540 million tons) were excavated from Canadian mines (1). The estimated value of the metals and industrial minerals was $1165 million.

Open pit operations accounted for 330 million tons of the total tonnage being made up of 150 million tons of ore and 180 million tons of waste. Even a slight decrease in the proportion of waste to ore would lead to substantial economic benefits and increased ore reserves. At present, the selection of pit slope angles is largely a matter of experience and engineering judgement. By being able through research, to steepen slopes by a few degrees could pay for itself one hundredfold.

In underground metalliferous mines future trends will be towards even deeper mining as known orebodies become depleted. This means greater problems in ground control which could lead to less extraction and more costly support systems. It is necessary to first evaluate present mining problems by developing the ability to predict ground reaction to mining, thereby increasing safety and avoiding waste of resources. In this way there will be an established basis for solving future problems at greater depth.

In recent years there has been a resurgence of the coal mining industry in western Canada. Both new underground mines and surface stripping operations are being developed. A number of long-term contracts for high tonnages have been signed, which ensures a stable market. However, some of the coal seams are prone to outbursts and are not mined beyond a depth of 600-700 ft. Much valuable coking coal is available beyond this depth. Consequently, if through research the ability is developed to prevent or control outbursts then this would significantly increase the viable coal reserves in western Canada.

(2) Planning Assumptions

That in the face of increased world competition the Canadian mining industry has to pioneer the development of mining technology and new mining systems. In which case less reliance has to be placed on trial and error procedures and intuitive judgement, and more on scientific procedures.

(3) Relation to Other Mines Branch Activities

Personnel in the ground control program also contribute to other Mining Research Centre programs. Considerable cooperative research is carried out with individual mining companies.

(4) National Need

The Canadian mining industry is large by world standards, being comparable in size to those in the U. S. A. and U. S. S. R. In addition mining in Canada is very diversified, ranging from the potash mines in Saskatchewan to the hard rock mines of the Canadian Shield. The multiplicity of ground control problems requires a scientific organization from which the mining company can obtain assistance in solving their problems.

The purpose of the ground control program is to develop rational procedures which will assist in designing underground openings and open pit slopes. This can be achieved through advancing new technology and in the development of new mining systems. Substantial economic and social benefits can result from research to improve safety, and to obtain maximum utilization or conservation of mineral resources.

Mining has long been considered as an "art" rather than a "science". Technological advances which have contributed to the progress of other engineering industries have, until recently, had no large impact on the mining industry. Over the last few decades the major advances in mining have been in the increased use of equipment; in drilling, raise boring, transportation and support systems. The design and the layout of mine openings both underground and on the surface are still mainly decided by experience, and trial and error procedures.

This lack of a scientific base has not hindered the advancement of mining in Canada. The occasions where ground control plays the major role in deciding mine design are probably the deep gold mines of Northern Ontario, the relatively deep potash mines in Saskatchewan and the Western coal mines. However, the picture is changing in that the vast low grade deposits mined by open pits require careful planning in slope design and predictable stability conditions, otherwise they are not economical. The trend is towards mining at greater depth underground, which implies greater ground control problems. This may mean modifications in mine design to maintain a safe working environment and economic extraction of the orebody. Many of the extensive coal deposits in western Canada are unmineable using present methods; this requires developing new mining methods.

Consequently, there is a need for research in ground control to ensure that the Canadian mining industry remains as competitive in the future as it has in the past.

(5) Alternatives

The alternatives are threefold: a) maintain the status quo, whereby mine design is evolved by engineering experience; b) import research from other countries; c) for the mining industry to do its own research.

(6) Criteria

Meaningful research usually takes a number of years to complete. Hence, to do research only when forced to is already too late. Therefore research into new technology and mining systems must be done now for implementation a few years hence. Due to the large mining industry in Canada, it is unrealistic to rely on other countries to solve our ground control problems. Rather Canada should take the lead in developing technology suitable for Canadian conditions. There is not much incentive for individual mining companies to do their own research. In many cases research has to be done in existing mines and the ensuing benefits may not be realised by that particular mine. However, the economic benefits for the industry as a whole could be considerable. In other cases a multi-discipline approach consisting of engineers, physicists, geologists and mathematicians is required, which is beyond the scope of most mining companies.

(7) Preferred Course of Action

The preferred course of action is for a government agency to carry out research in ground control which is relevant to the whole mining industry.

(8) Project Titles and Technical Objectives

a) Slope Stability

A multi-discipline approach is being undertaken on this problem in cooperation with some mining companies. The technical objectives are:

1) To predict the stresses and displacements of various slope configurations using finite element techniques.

2) To investigate failure criteria of pit slopes by means of back analysis of existing slope failures.
3) To define the location and magnitude of rock-mass movement using borehole extensometers and surveying instruments.

Progressing from the research to the development stage comprises artificially reinforcing slopes using cable bolts. In certain cases this has been shown to be economically feasible (2)*, allowing steeper slopes to be mined. Since the cost of such a support system is large, it requires active cooperation from a mining company to take this method from the development stage to an accepted mining practice.

b) Stability in Underground Metalliferous Mines

Practical research is being carried out in mines throughout Canada. The technical objectives are:

1) To investigate the support offered by backfill and its effect on the surrounding strata in steeply dipping orebodies.
2) To evaluate the types of support used in block caving operations in an attempt to predict the type of support required for various ground conditions.
3) To improve roof stability in salt strata and evaluate the effectiveness of rock bolting.
4) To determine the effect of geologic structure on both the stresses within and the strength of the rock-mass surrounding mine openings.

Rock mechanics instrumentation and accessory equipment suitable for conditions in Canadian mines are evaluated. Information on those which are found suitable is made available to the mining industry through publications (3).

c) Strata Control in Coal Mines

A Western Office was established in Calgary in 1970, expanding the research effort being directed towards coal problems. Studies concerned with gas outbursts and roof stability are now underway. The preliminary technical objectives are:

1) To define the problem on gas outbursts and establish the geological and physical parameters which contribute.

2) To investigate the stability of the roof in access roadways of a longwall face operation, by monitoring roof deformation and loads on bolts as longwall operations proceed.

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*See References

(9) Projected Costs and Scheduling (1972-1975)

a) Slope Stability

	Man-years	Cost/man-year	Total
Professional	9	15,000	$ 135,000
Technical	4.5	8,000	36,000
			171,000
Overheads			171,000
			$ 342,000

b) Stability in Underground Metalliferous Mines

	Man-years	Cost/man-year	Total
Professional	10.5	15,000	157,500
Technical	4.5	8,000	36,000
			193,500
Overheads			193,500
			$ 387,000

c) Strata Control in Coal Mines

	Man-years	Cost/man-year	Total
Professional	13.5	15,000	202,500
Technical	6	8,000	48,000
			250,500
Overheads			250,500
			$ 501,000
Total Input 1972-1975			$1,230,000

(10) Benefits

a) Stability of Open Pit Slopes

It is judged that the planned research and development should lead to an average increase in slope angle of at least one degree. Even reducing the amount of waste excavated by 0.2% (at $0.34/ton) or increasing ore production by 0.06% (at $1.20/ton) would pay for all the projected costs of the research project. A one degree increase in slope would result in a 3% reduction in waste excavation. Taken at the 1970 level of about 250 million tons of waste excavated, this would result in a cost saving of $2.5 million/year.

b) Stability of Underground Metalliferous Mines

Major benefits will accrue from: conservation of mineral resources by means of higher extraction; improvement of mining environment, such as condition of the roof to increase safety of working places; attainment of better value for the cost of support systems; and an increase in the effectiveness of rock or sand fill to permit easier extraction of the whole orebody. Financial savings are difficult to determine since the major benefits are in the area of improved working conditions and more efficient operations.

c) Strata Control in Coal Mines

Successful research into control or prevention of outbursts would make available large reserves of coal which are currently unobtainable. Control of methane emission would effectively increase face operating times and decrease ventilation problems. Mine safety from both ground control and fire hazard considerations would be greatly improved. Improvement in roof stability would lead to more efficient room and pillar and longwall operations. Long-term contracts for the next 15 years require production of 204 million tons of coal valued at $2.57 billion (4). The above problems probably will have to be solved to efficiently and economically reach this output. Hence the financial returns on this research could be considerable.

(11) Estimate of Input/Output of the Research Projects

	Input	Output	Ratio
a) Stability of Open Pit Slopes	342,000	7,500,000	22:1
b) Stability of Underground Metalliferous Mines	387,000	--	--
c) Strata Control in Coal Mines	501,000	--	--

(12) References

(1) Mines Branch Memo, Report ADM 70-5, 1970.
(2) Barron, K., Coates, D.F. and Gyenge, M., "Artificial Support of Rock Slopes", Mines Branch Research Report R 228, July 1970.
(3) Barron, K., Hedley, D.G.F. and Coates, D.F., "Field Instrumentation for Rock Slopes", Sym. on Stability and Surface Mining, Vancouver, Nov. 1970.
(4) Zorychta, H., "Developments in Coal Mining - 1969", C.I.M. Bull., Oct. 1970.

Sub-Activity 2 - Rock Breakage - Explosives Research

(1) Situation

Research in this area contributes to the objectives of advancing new technology, improving safety in mining operations and transporting explosives and developing new systems. Continued research efforts are necessary during the next ten years to improve conventional drilling and blasting operations, which will remain the dominant mining method for the time being, until continuous mining comes of age. The development of slurries and slurry-loading systems for underground mining would permit these operations to enjoy some of the advantages which are at present limited to open pit operations. Research leading to a better understanding, and as a result a better control, of fragmentation would be of advantage to both underground and open pit operations. At present the discontinuity of operations underground is accentuated by the lack of control over fragmentation, which necessitates secondary breakage. Lack of fragmentation control and oversize rock are major causes of equipment breakdown. Greater use of long-hole drilling and larger-sized holes is envisaged in underground mining. A field study to appraise the cost effect of various factors on long-hole drilling suggests that research is warranted with respect to hole pattern layout, drill steel design, and drilling machine design.

Although fatality and accident rates in mining are no worse than in comparable resource industries, they are an order of magnitude greater than frequencies in secondary industry. With regard to safety, the records show that air pollution by toxic elements is greater in some mines than in big cities. With regard to attracting labour and providing efficient working conditions, the noise and lighting environments compare poorly with other industries.

The high level of innovation in producing new explosives and other hazardous materials is providing an increased requirement for research and testing so that safe methods, without excessive precautions, can be established for manufacturing, transportation and handling. During the past few years the ability to relax transportation precautions on certain classes of insensitive explosives, as the result of projects conducted within this activity, has resulted in savings to industry of over $1 million per year.

(2) Planning Assumptions

The mining industry provides about 30 per cent (about $3.5 billion) of the yearly Canadian export dollars. It is estimated that yearly 130 million dollars is spent by the mining industry in drilling and blasting a total of 600 million tons of ore and waste rock. Considered separately, the explosives industry yearly produces about 300 million pounds of explosives with the total value of 100 million dollars. A modest improvement in rock breakage based on a more thorough knowledge of rock and explosives properties and their influence on blasting action would lead to a considerable financial savings to the Canadian mining industry.

The introduction of refinements to existing mining methods and techniques or the introduction of new techniques at any phase of mining operation will have effect on the total operation. Consequently operations such as crushing, grinding and milling are included within the scope of this activity.

The need for research in these fields is coupled with the importance of conserving of our inheritance of non-renewable resources for optimum economic exploitation. The necessary research is carried out with regard to the requirement of minimizing damage to external environment and with regard to the protection of the public from the hazards associated with the use of explosives and other consequences of mining.

(3) Relation to Other Mines Branch Studies

The work is done primarily at the Canadian Explosives Research Laboratory, at the Elliot Lake Laboratory and at the Rock Mechanics Laboratory. However, one of the projects is conducted as a team effort with the Mineral Processing Division and with the Extraction Metallurgy Division.

(4) National Need

The Canadian mining industry should maintain and possibly expand its over-all position as one of the world's leading mineral producers. This will require continued technological changes, notably those which would help to provide more jobs in the mining industry with a higher sociological status. Technological changes will also be required to provide an improved working environment, to minimize the effect of mining on the ecology, and to exploit more fully, in terms of grade and total recovery, the resources being mined.

(5) Alternatives

(a) Establishment of the necessary facilities at individual mines for solution of pressing problems.
(b) Conducting the research at universities on specific subjects.
(c) Establishment of a central institute for rock breakage and explosives research on problems of all companies, financed by the entire industry.
(d) Undertaking the research by the Mines Branch, giving priority to the problems of national interest.
(e) Establishment of a mining research laboratory, specializing in the area of rock breakage, in the Province of Quebec, in order to conduct the research work as close to areas of application as possible.

(6) Criteria

To conduct the research in the manner that will ensure the effective use of mineral and energy resources available in Canada for the present and future benefit of the nation.

(7) Preferred Courses of Action

Since both alternatives, (d) and (e), equally are suitable to fulfill the research criteria and objectives, either of them could be selected as the preferred course of action.

(8) Project Titles and Technical Objectives

a) Tunnelling Machine

The objective of this project is the development of new concepts of primary rock breakage.

b) Mathematical Simulation of Grinding Circuits

The project was initiated with the objective to gain a thorough understanding of the methods of mathematical analysis of crushing and grinding circuits, using the computer. The project will serve as a background study necessary in the development of sensors for control devices.

c) Blasting Research

The objective is to develop production blast design criteria. It is planned to investigate the possibility of introducing additional energy absorbing processes to the elemental charge stress analysis.

d) Iron Mine

The objective is to evaluate pre-splitting as a means of reducing the structural damage occurring in berms as a result of production blasts.

e) Explosives Testing and Evaluation

One of the functions of the Canadian Explosives Research Laboratory is the provision of technical expertise to Canadian regulatory and other agencies responsible for the correct use, storage and transportation of explosives and dangerous goods in Canada. The services provided are mainly at the request of the Chief Inspector of Explosives, but an increasing amount is being requested by such agencies as the Post Office Department, Materiel Command, DND, the Department of Transport and the Railway Committee of the Canadian Transportation Commission. In order to adequately provide these services with the continuing introduction of new tests, new materials and new classifications, research work is required to evaluate the effectiveness of new tests and the hazards of new materials as they are introduced. The laboratory with regard to the above function is unique in Canada serving a group of regulatory agencies with no comparable staff or facilities.

(9) Projected Costs and Scheduling

a) Tunnelling Machine

Professional	5 years (15,000)	$ 75,000	1972-1975
Technician	4 years (8,000)	32,000	1972-1975
Equipment		35,000	1972-1975
		$142,000	
	Overhead	113,000	
		$255,000	

b) Mathematical Simulation of Grinding Circuits

Professional	6 years (15,000)	$ 90,000	1972-1975
Technician	4 years (8,000)	32,000	1972-1975
		$122,000	
	Overhead	89,000	
		$211,000	

c) Blasting Research

Professional	7 years (15,000)	$105,000	1972-1975
Technician	6 years (8,000)	48,000	1972-1975
Equipment		17,000	
		$170,000	
	Overhead	124,000	
		$294,000	

d) Iron Mine

Professional	3 years (15,000)	$ 45,000	1972-1975
Technician	2 years (8,000)	16,000	1972-1974
Equipment		2,000	1972-1973
		$ 63,000	
	Overhead	48,000	
		$111,000	

e) Explosives Testing and Evaluation

Professional	12 years (15,000)	$180,000	1972-1975
Technician	15 years (8,000)	120,000	1972-1975
Equipment		15,000	1973-1975
		$315,000	
	Overhead	240,000	
		$555,000	

(10) Benefits

a) Tunnelling Machine

The expected benefit is the development of a safe, reliable, low capital cost tunnelling machine with a high degree of flexibility that would be adaptable enough to operate over a wide range of ground conditions at a reasonable rate of penetration.

b) Mathematical Simulation of Grinding Circuits

The expected benefit is the development of techniques for optimization of grinding circuits.

c) Blasting Research

At present 120 million dollars per year is spent on drilling and blasting. If through the development of a better blasting criteria a 5% reduction in drilling and blasting costs can be obtained then a savings of 6 million dollars per year could result.

d) Iron Mine

Evaluation of the effectiveness of pre-splitting as a means of reducing berm damage. Consequently, the stability of pit walls will be increased and therefore safer working conditions will be resulted.

e) Explosives Testing and Evaluation

Approximately 60% of the 300 million pounds of explosives used in Canada is classed as Class II explosives. It is estimated that the savings in transportation occurring from this classification is 1.5 million dollars per year. The continued existence of this classification with its savings is dependent on the ability through tests to exclude formulation which represent an undue hazard for this classification. Classification tests must increase in sophistication with the increase in sophistication of blasting agent formulation.

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Sub-Activity 3 - Mine Systems Engineering Research

(1) Situation

New technology is required in mining not only to increase efficiency but also to obtain means of predicting stability of mining excavations and other structures to increase the extraction from mineral reserves, to provide safe working conditions and to preserve the environment.

Mining can be characterized by the great and unpredictable changes in operating conditions. One result of this factor is that mining engineering has always had a much larger element of judgement and a smaller element of analysis than other areas of engineering. Today and in the future better predictability must be obtained to be able to use the new scientific and industrial developments such as those leading to improved operations control and the continuous rather than batch mining methods that are necessary for automation.

It has become increasingly evident over the past few years that the sensing of rock stability conditions and of ore grade beyond the face is becoming increasingly important. Such advanced information is required to avoid losses of production and the heavy costs associated with delays in an increasingly capital intensive activity.

(2) Planning Assumptions

Currently over 250 million tons per year of ore are excavated from open pits, which require at the same time the excavation of approximately 250 million tons of waste. A study of the research required to decrease the proportions of waste excavation, and thereby greatly increase reserves, together with a careful examination of the benefits that would or would not accrue to each open pit mine in Canada, shows a prospective benefit/cost ratio of approximately 100:1. Similarly, in underground mining, the determination of whether support is required or not, and if required, what is the cheapest kind of support, is important to many operations. These questions become increasingly critical with depth.

Research in these areas contributes to the objective of advancing new technology in mining by demonstrating the application of operations research and automation.

(3) Relation to Other Mines Branch Studies

Generally the projects of the Mine Systems Engineering Activity are handled in close cooperation between the Elliot Lake Laboratory and the Rock Mechanics Laboratory. Exception is the In-Situ Mining joint project, where at the present stage of the project the primary responsibility lies with the Extraction Metallurgy Division.

(4) National Need

Canadian mining, with the gross earnings of $1.5 billion per year, could become a world leader in the technology required for production, exploration, pollution abatement and conservation. The primary requirement to achieve such a goal is to have the will to do it, the benefits would be manifold.

With the fact that the competition is becoming more severe, together with the reduction in average grade, the deepening of mining operations and the escalation of demands of labour point to the increasing need in a defensive sense for research that will continuously improve productivity, working conditions and conservation.

In addition, there is some evidence that U.S. entrepreneurs in Canada are more readily supported by banks and local governments than are their Canadian counterparts. These service organizations apparently do not have the same confidence in Canadian management. Again government enterprise could possibly influence this situation by research in such areas as system analysis and automation to improve the management and technical quality of Canadian enterprise and thereby increase the sense of confidence in the ancilliary organizations.

The development of mining methods that will permit the extraction of theoretical reserves is quite important from the national point of view. For example, much of the geologically estimated volumes of western coal are not mineable by present methods. Furthermore, no other country has a similar interest in these problems so that the situation is quite clear—we must solve them ourselves.

(5) Alternatives

(a) Establishment of mining research facilities at the mines to solve the problem of the individual mines.
(b) Conducting the mining research at the universities on circumscribed subjects.
(c) Establishment of a central institute for research on the problems of all companies, financed by the entire industry.
(d) Undertaking the research by governmental enterprise, giving priority to the problems of national interest.

(6) Criteria

To conduct the research in the manner which ensures the effective use of mineral and energy resources available in Canada for the present and future benefit of the nation.

(7) Preferred Courses of Action

For adherence to the criteria and to the objectives of the activity the preferred course of action is the governmental research.

(8) Project Titles and Technical Objectives

a) Blasthole Drilling Analysis

The lengths and inclination of the boreholes of a blasthole ring are dependent upon the geometrical location of the drilling drift within a blasthole stope. Drilling times required to drill the blastholes depend on the drilling performance, which depends again on several factors such as the drill, drill rods, diameter, inclination and lengths of the hole. The objectives of this project are:

(i) To establish the major influencing variables and the relationship between them and to the drilling time.
(ii) To find the optimum location of the drilling drift when the total drilling cost of a ring pattern is the minimum.
(iii) To make recommendations of changes in order to improve the drilling performance.

b) Optimization of Open Pit Blasting

Optimum blasting in an open pit may be defined as the blasting practice which gives the degree of fragmentation necessary to obtain the lowest unit cost for the combined operations of primary breakage, secondary breakage, loading, hauling and primary crushing. The objective of this project is to establish the optimum blasting practice.

c) In Situ Mining

The objective is to develop techniques of in situ mining (leaching) of metals, thereby enabling lower grade ores to be included within the nation's ore reserves.

d) Operations Control

The ultimate objective is to apply a range of sensors to the various mining operations, to develop data transmission, display, logging analysis and reporting systems, and hence to provide mine superintendents with enhanced techniques for control operations. Subsequent to the logging of operating data, the empirical relations between various technical and economic factors could be subject to analyses leading to optimization studies that might affect mine design, operating sequences and equipment selection. If a realistic model of the operations could be developed, a feedback connection to the sensing system might lead to automated mining.

The immediate objectives are:

(i) Automating of raise borers.
(ii) Development of methods whereby unbiased estimates of ore reserves can be calculated from the exploration drill-hole data.
(iii) Development of method to add the measured amounts of bentonite with even distribution in the process of iron ore pelletization.

(9) Projected Costs and Scheduling

a) Blasthole Drilling Analysis

Professional	3 years (15,000)	$ 45,000	1972-1975
Technician	1 year (8,000)	8,000	1974-1975
		$ 53,000	
	Overhead	42,000	
		$ 95,000	

b) Optimization of Open Pit Blasting

Professional	5 years (15,000)	$ 75,000	1972-1975
Technician	3 years (8,000)	24,000	1972-1975
		$ 99,000	
	Overhead	78,000	
		$177,000	

c) In Situ Mining

Professional	3 years (15,000)	$ 45,000	1972-1975
Technician	1 year (8,000)	8,000	1974-1975
Equipment		5,000	1974-1975
		$ 58,000	
	Overhead	42,000	
		$100,000	

d) Operations Control

Professional	9 years (15,000)	$135,000	1972-1975
Technician	6 years (8,000)	48,000	1972-1975
Equipment		72,000	1972-1975
		$255,000	
	Overhead	147,000	
		$402,000	

(10) Benefits

a) Blasthole Drilling Analysis

The drilling cost is the largest single item of the total cost of blasthole stoping operations. In order to decrease the operating costs, therefore, the logical area of research for improvement is directed towards drilling. The project could yield a guideline in designing operations more economically.

b) Optimization of Open Pit Blasting

The ore produced annually from open pits amounts to 150 million tons. Assume that as a result of this research project a 5% savings in cost is achieved in 1/3 of the open pit mines in Canada. Consequently, the potential value of successful research at an average combined cost of drilling, blasting, loading, hauling and crushing of $1.10/ton is approximately 2.75 million dollars per annum.

c) In Situ Mining

Initially the benefit would be an advance in knowledge of leaching, part of which may be immediately applicable in stope remnant leaching now practiced in Elliot Lake. The long-term benefit could be, as a minimum, the doubling of Canadian reserves of uranium, and substantial increases in reserves of other leachable ores. The full benefit of practical results cannot be estimated.

d) Operations Control

Conventional methods of ore estimation usually over-estimate the amount of metal in the ground. Successful application of geostatistics would give the operators unbiased estimates of anticipated production together with knowledge of their confidence limits.

Another expected benefit, in relation to raise boring, would be the operation of raise borers with less maintenance problems, since the control system should react to prevent over-loading and subsequent breakdowns.

Generally speaking, fully automated mining will come about by evolution as various stages of mining are individually automated. We are taking the first steps in this direction.

As regards bentonite addition, a solution of this problem would result in worthwhile savings in the cost of bentonite as well as in more uniform bentonite/ore mixtures.

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Sub-Activity 4 - Environmental Control Research

The environmental control sub-activity is directed toward improving the quality of the air breathed by miners, thereby eliminating or alleviating lung diseases caused by dust and other pollutants produced by the mining process. More specifically the activity is concerned with dust physics and the relationships that exist between the rock mined, the mining process and the respirable dust and other pollutants created.

The Canadian mining industry, widespread and diversified, is vulnerable to the sociological changes caused by public awareness of the relationship of man's health to his work environment. Labour has demanded and received consideration; legislation has forced higher standards of safety; and the industry has borne ever increasing assessment costs. In spite of the excellent pioneering work by industry and government in the fields of physiotherapy, therapeutics, ventilation and dust control, lung diseases still develop in miners, and dust and airborne pollutants are still an occupational hazard in mines.

Environmental control research contributes to the objective of improving working conditions in mines. The contribution consists of 11 man-years and $167,000 representing physicists, a chemist, and an engineer plus supporting staff. At the prompting of industry, consideration is being given to requesting an expansion of this activity to some research on control measures and on noise suppression. A ventilation engineer and a physicist together with supporting personnel at a cost of $80,000 per year would be required to make a contribution in these areas.

(1) Situation

Respirable dust has long been recognized as the cause of pulmonary diseases. Mining because of the dust-creating nature of the industry contributes heavily to the toll of chest diseases in the form of a work-related disease called pneumoconiosis.

In Canada, as in most highly industrialized countries, modern mining technology aggravates the respirable dust problem. Unfortunately dust control technology has not kept pace with production technology in Canada. Consequently what was a health problem in mines now threatens to become a serious problem of top level and national importance, particularly if more effective control of mine environments is not forthcoming. Effective control of mine environments can only be achieved by the judicious application of current knowledge through the coordinated efforts of government, university and industry.

(2) Planning Assumptions

The Canadian mining industry is expected to face more stringent health regulations in the near future. To ensure these regulations are practical and applicable, legislated techniques and standards must be based on the best research of scientists and experience of operators. In brief, relevant data must be generated both in the laboratories and in the mines.

(3) Relation to Other Mines Branch Studies

Cooperative research is being carried out with Mines Branch Mineral Sciences Division on a periodic basis. Personnel skilled in the use of X-ray and infrared equipment in the Mineral Sciences Division are working on field samples taken by the Environmental Control Group in an attempt to determine the most suitable and effective methods of analyzing the composition of as-received airborne dust samples. In addition, a study is underway to design and develop a field instrument for quartz determination.

Within the Mining Research Centre the Environmental Control Group utilizes the workshop, electronic services, and special skills of other groups within the Centre. In total, approximately 15 per cent of the Centre's effort and 18 per cent of its budget is utilized in the Environmental Control Research Sub-Activity.

(4) National Need

In the absence of a national dust control program or policy for mines, the onus rests with the research workers, operators and provincial authorities to cooperate and to coordinate their efforts if objectives are to be realized. Only through such efforts will the Canadian mining industry be able to participate in the expanding markets predicted for the future. Failure to come to grips with the health problems will jeopardize the industry's position not only in the export market but also in the labour market.

(5) Alternatives

Allow provincial and industrial agencies to meet the problem as best they can. Ill-based legal codes will eliminate many producers in the face of expanding markets. (If control is exercised on a trial-and-error basis, mining costs will rise, disability compensation costs will rise and consequently high-grading low cost resources will occur).

(6) Criteria

The mining companies and provincial governmental agencies cannot carry the basic and experimental research required to isolate the dust hazards peculiar to mining operations. Probably this is because of the multi-disciplinary approach required. Once the science of measurement is established and the reproducibility and accuracy of data are ensured, the mining companies will be able to dedicate their efforts to effective control.

(7) Preferred Course of Action

The preferred course of action is to carry out research and development projects to establish instrumentation and techniques adaptable to the diversity of conditions met in Canadian mines. To use these instruments to determine the effectiveness of current control methods to reduce dust hazards in mines.

In addition, it is necessary from time to time to enter into a short-term dust suppression study to assist with the alleviation of a current and threatening health problem.

(8) Project Titles and Technical Objectives

a) Comparative Dust Measurement

The objective of this study is to develop a single parameter dust measuring technique suitable for routine use in Canadian mines. The immediate objective is to determine from the assessment of available measuring techniques those which are most applicable and which match Canadian conditions.

b) Dust from Canadian Rocks

The objective of this project is to study the relationship between the physical and mineralogical properties of rock and the concentration, composition and size distribution of the airborne dust produced during the mining of these rocks.

c) Clean-up of Mine Air by Underground Filtration

The objective is to study the relationship between airborne dust and radon daughters and to determine the feasibility of reducing radioactivity by filtering dust from mine air. Various filter media—industrial, commercial, make-up—are being tested.

d) Calibration of Laboratory and Field Equipment for Radon Studies

The objective is to prepare suitable standards and to calibrate laboratory and field equipment.

(9) Projected Costs and Scheduling (1972-1975)

a) Comparative Dust Measurements

	Man-years	Cost/man-year	Total
Professional	3.4	15,000	$ 51,000
Technician	3.0	8,000	24,000
			75,000
Plant, service, overhead			75,000
			$150,000

b) Dust from Canadian Rocks

	Man-years	Cost/man-year	Total
Professional	4.4	15,000	$ 66,000
Technician	5.0	8,000	40,000
			106,000
Plant, service, overhead			106,000
			$212,000

c) Clean-up of Mine Air by Underground Filtration - Complete in 1971

	Man-years	Cost/man-year	Total
Professional	0.7	15,000	$ 3,000
Technician	0.3	8,000	2,400
			5,400
Plant, service, overhead			5,400
			$ 10,800

d) Calibration of Laboratory and Field Equipment (radioactive dusts)

	Man-years	Cost/man-year	Total
Professional	5	15,000	$ 75,000
Technician	8	8,000	64,000
			139,000
Plant, service, overhead			139,000
			$278,000

Total Input, 1972-1975	$150,000
	212,000
	10,800
	278,000
	$650,800

(10) Benefits

a) Comparative Dust Measurements

More realistic appraisal of dust hazard in mines should be the most important outcome of the research. A strong scientific and technological basis for pre-mining design and legal technical codes should be established to safeguard the health of mine workers and maintain environmental quality.

Sampling costs should be reduced by 10 per cent minimum but most important will be the saving in dust control costs when the hazard not the total dust is considered. A saving of $400, 000 per year to the mining industry is not unrealistic.

b) Dust from Canadian Rocks

Knowledge of the expected airborne dust production and the health hazard could be useful in assessing the ventilation requirements in a new mine. The capital and running costs for a mine with a life of 10 years would be about $2, 000, 000. This project would save a minimum of 1 per cent of the capital outlay alone, $200, 000. The running costs would decrease accordingly and would most likely exceed 1 per cent.

c) Clean-up of Mine Air by Underground Filtration

Substantial economic advantages are envisaged if large volumes of contaminated air can be cleaned and recirculated. A conservative estimate is $50, 000 to $100, 000 per year for the average uranium mine in the Elliot Lake area.

d) Calibration of Laboratory and Field Equipment (radioactive dusts)

This project is required in order to establish the sensitivity, accuracy and reproducibility of all laboratory experimental measurements and many field experimental measurements. It will provide the data for evaluation of field instruments in routine use by the mines and for the development of improved and more economical instruments and techniques.

(11) Estimate of Input/Output of the Research Projects

	Input	Output	Ratio
a) Comparative Dust Measurements	450,000	1, 200, 000	3:1
b) Dust from Canadian Rocks	212,000	600, 000	3:1
c) Clean-up of Mine Air	10,800	75, 000	7:1
d) Calibration of Laboratory and Field Equipment	278,000	--	--

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MINING ACTIVITY: 3-YEAR FORECAST

SUB-ACTIVITY AND		Man Years			Cost/	Total
SUB-SUB-ACTIVITY	PTO	72/73	73/74	74/75	Man Year	3 Years
Ground Control Research						
Slope Stability	P	3	3	3	15,000	135,000
	T	1.5	1.5	1.5	8,000	36,000
	O					171,000
						342,000
Stability in Underground Metalliferous Mines	P	3.5	3.5	3.5	15,000	157,500
	T	1.5	1.5	1.5	8,000	36,000
	O					193,500
						387,000
Strata Control in Coal Mines	P	4.5	4.5	4.5	15,000	202,500
	T	2	2	2	8,000	48,000
	O					250,500
						501,000
Rock Breakage - Explosives Research						
Tunnelling Machine	P	1.7	1.7	1.7	15,000	75,000
	T	1.3	1.3	1.3	8,000	32,000
	O					148,000
						255,000
Mathematical Simulation of Grinding Circuits	P	2	2	2	15,000	90,000
	T	1.3	1.3	1.3	8,000	32,000
	O					89,000
						211,000
Blasting Research	P	2.3	2.3	2.3	15,000	105,000
	T	2	2	2	8,000	48,000
	O					141,000
						294,000
Iron Mine	P	1	1	1	15,000	45,000
	T	1	1	-	8,000	16,000
	O					50,000
						111,000
Sub-Total		28.6	28.6	27.6		1,759,800

P = Professional T = Technician O = Overhead including equipment and supplies

SUB-ACTIVITY AND SUB-SUB-ACTIVITY	PTO	Man Years			Cost/ Man Year	Total 3 Years
		72/73	73/74	74/75		
Brought Forward		28.6	28.6	27.6		1,759,800
Explosives Testing and Evaluation	P	4	4	4	15,000	180,000
	T	5	5	5	8,000	120,000
	O					255,000
						555,000
Mine Systems Engineering						
Blasthole Drilling Analysis	P	1	1	1	15,000	45,000
	T	-	-	1	8,000	8,000
	O					42,000
						95,000
Optimization of Open-Pit Blasting	P	1.7	1.7	1.7	15,000	75,000
	T	1	1	1	8,000	24,000
	O					78,000
						177,000
In-Situ Mining	P	1	1	1	15,000	45,000
	T	-	-	1	8,000	8,000
	O					47,000
						100,000
Operations Control	P	3	3	3	15,000	135,000
	T	2	2	2	8,000	48,000
	O					219,000
						402,000
Environmental Control Research						
Comparative Dust Measurements	P	1.1	1.1	1.1	15,000	51,000
	T	1	1	1	8,000	24,000
	O					75,000
						150,000
Dust from Canadian Rocks	P	1.5	1.5	1.5	15,000	66,000
	T	1.7	1.7	1.7	8,000	40,000
	O					106,000
						212,000
Sub-Total		52.6	52.6	53.6		3,450,800

SUB-ACTIVITY AND SUB-SUB-ACTIVITY	PTO	Man Years			Cost/ Man Year	Total 3 Years
		72/73	73/74	74/75		
Brought Forward		52.6	52.6	53.6		3,450,800
Clean-up of Mine Air by Underground Filtration	P	0.2	-	-	15,000	3,000
	T	0.3	-	-	8,000	2,400
	O					5,400
						10,800
Calibration of Laboratory and Field Equipment (radioactive dusts)	P	1.7	1.7	1.7	15,000	75,000
	T	2.7	2.7	2.7	8,000	64,000
	O					139,000
						278,000
TOTAL, MINING ACTIVITY		57.5	57.0	58.0		3,739,600

2. MINERALS AND METALS TECHNOLOGY ACTIVITY POSITION PAPER (MAY, 1971)

Objective

> "To ensure the most effective conversion and use of minerals and metals".

Introduction

The sub-objective of "ensuring the most effective conversion and use of minerals and metals" is pursued with the background in mind that was provided in the "Program Forecast Review, 1972/73", of January 15, 1971:

> "Mines Branch Span of Activities....... are pursued in the present context of increased world production, depletion of the higher grade mineral resources in Canada and public demand for minimal damage to the environment. The goal of these activities is to add significantly to the scientific and technological know-how required by industry and government to manage our mineral resources most effectively for Canada's benefit."

The conversion and use of minerals and metals covers a wide range of activities. The conversion begins with the raw ore received from the mine, passes through multi-stage processes of concentration, extraction and treatment to products that find uses as metals, and a host of mineral products, all vital to Canada's economic well-being and future prosperity. The objective of the Mines Branch is to ensure that these conversions are carried out in the most efficient manner, with the least loss of valuable constituents and with a minimum damage to the environment. The reference to the word 'use' in the sub-objective implies that, to the greatest degree possible, our minerals and metals are processed and manufactured in Canada for the benefit of Canadians. It implies that our resources are, in fact, used and not left in the ground as a result of short-term expediency or lack of technology, and that these mineral resources are used to the greatest advantage of all Canadians.

Background and Scope

Technological change is a dynamic and all-pervading force in the economic, social and cultural life of a country. One of the most respected economists of our age, Sumner Slichter, in speaking to the National Sciences Foundation in the United States, stated:

> "Today it is unthinkable that anyone should attempt to construct a theory of employment or a theory of growth without taking account of technological research. Within the last thirty years technological research has become a large operation that introduces fundamental changes into the operation of the economy."

The impact of technology on Canada's mineral and metal industries which accounted for about $4 billion in production in 1970 and about thirty percent of Canada's total commodity exports, need not be further laboured in this paper. Suffice to say that it is vital and will continue to play an even more important role in the growth of Canada's mineral industries. The area that must be examined here is the contribution of the Mines Branch in advancing technology in the processing and use of minerals and metals to meet Canada's national needs.

Before going any further it may be helpful, in examining the implications of technology, to look upon production, consumption, and use of mineral raw materials in terms of the "Systems Approach": the System accepts ores and minerals at their points of origin, transforms them by a multi-stage process, producing both desirable and undesirable outputs; and, to an increasing extent, the System incorporates a re-cycling link by which valuable constituents are recovered from waste materials. The management of this System (using the term in a very broad sense) is one of the prime government concerns, with inputs from the three sectors—industry, education, and the government. The System is not isolated--interaction occurs with social-economic systems that produces a multitude of consequences for the nation; neither is it static, for not only is there a continual flow of minerals and materials through the System but they change in both quantity and kind with time.

This System concept emphasizes the broad scope of activities covered by the sub-objective. For this reason a large proportion, i.e., over fifty percent of Mines Branch resources are committed to activities covered under this sub-objective. At the raw materials end of this System we are concerned with mineral sciences and technology, including all the stages of recovery; at the product end of the term "Materials Science", in which properties and end uses of materials receive attention, is more appropriately descriptive of the type of R and D performed.

National Need

Mines Branch activities occupy a unique position in Canada in the fields of minerals and metals technology, a situation which stems from its interdisciplinary capabilities as a national laboratory, the close associations it has with others in the Department and government working in related areas, e.g., energy, anti-pollution, minerals development, and its ability as a national laboratory to recognize and respond to needs arising from long-term national developments. Guidelines used in pursuing R and D goals under this heading take into consideration the gaps that must be filled between the activities of industry, primarily occupied with the shorter term interests of cash-flow, profitability and other such items that affect day-to-day operations, and the basic research carried out at universities. We must also consider the special needs that are peculiar to Canada:--the physical environment, e. g., the sub-zero temperatures associated with much of our north that places special demands on metals and construction materials and the difficulties encountered in operating processing plants under such conditions; Canada's competitive position in relation to a number of mineral commodities that are being produced in increasing quantities in other countries and which is affected by our spiralling costs of production that are so closely tied to the cost of labour. Our environment is, of course, receiving a great deal of attention these days and major steps have been taken to undertake R and D activities and introduce regulations that are intended to improve existing conditions and make better plans for the future. It does not burden the imagination too much to understand that, for the mineral industries, the extraction and processing stages of mineral and metal production are the obvious starting points in our attempts to achieve acceptable limits of pollution in air, water, and land.

One of the special needs that must be considered in Canada relates to those situations where industries are composed of a number of small companies that, in general, are unable to take advantage of new technology. This may be because they are too small to support any viable R and D effort on their own, or they may be just technologically unaware to profit from the opportunities and avenues for future growth that exist. An example of such a situation are the many small plants processing metals and alloys into useful products by casting, hot working, welding and powder metallurgy, which includes several hundred small foundries. In the field of industrial minerals the Brick Manufacturing Industry represents a situation where a relatively large number of small plants have come to rely almost entirely on Mines Branch capabilities to help solve problems and provide guidance in future developments.

Minerals resources have been defined as naturally-occurring materials--minerals and rock--that can yield a product which may be used by man. This may lead to the misconception that resources are fixed in quantity, and hence are exhaustible according to a pre-determined schedule. From a practical point of view, however, this is not true - the fact being that resources are created by research; research that develops new uses for raw materials, and research that permits the recovery of ores of lower quality than were previously mineable. Thus, by increasing recovery in processing, by extending the process to extract other materials economically, by the re-cycling of waste materials and converting the waste to useful products, we are extending the mineral resources potential.

Walter Hibbard, the recent Director of the U.S. Bureau of Mines, stated that one of the objectives of the United States was to ensure an adequate and dependable flow of minerals in the national interest:

> "Accomplishing this objective requires that government have a wider choice among alternative policies and programs and that it be able to foresee with constantly improving clarity what the effects of each alternative will be. In too few instances today can we do this with any degree of confidence in our results. Often we are stymied by the lack of pertinent data or because basic information about the industry or trends within the industry is not available."

Although the Canadian situation with respect to minerals and metals is substantially different from that of the United States, our policies must equally be based on pertinent data and on a knowledge of industrial technology and capabilities. The Mines Branch, in pursuing its objective of ensuring the most effective conversion and use of minerals and metals, contributes significantly to the supply of up-to-date information on which policy decisions can be confidently based.

The sub-objective, "Minerals and Metals Technology" is further described in this position paper under six sub-sub-objective headings:

1.) To improve on methods of minerals and metals recovery.
2.) To ensure the most effective use of scarce mineral and metal resources.
3.) To ensure the most effective conversion of industrial minerals to useful products.
4.) To ensure the most efficient processing of metals and alloys.
5.) To ensure the most effective utilization of metal and mineral products.
6.) To ensure a national awareness of trends and changes in the technology and use of minerals and metals.

Under each of the headings the sub-sub-objectives are elaborated upon, giving background information, additional explanation of the objectives, and examples of activities that illustrate the type of work carried out in pursuit of the objective.

Sub-Sub-Objective 1

"To improve on methods of minerals and metals extraction"

The profitability of the Canadian mineral industry is a matter of national concern, since it is through the mineral industry that the Canadian resources of minerals and metals are turned into national wealth, providing Canadians with useful products, employment and opportunities for investment. However, the Canadian mineral industry competes for markets with the mineral industries of other countries. Consequently, it is in the national interest that our industry be encouraged to utilize technology to the maximum to continually improve its methods for the extraction of minerals and metals. This can only be achieved through a continuous program of research and development. Such a program, for maximum effectiveness from a national point of view, should take into account the known Canadian resources of minerals and metals, the processing problems that are of importance to the mineral industry generally, and estimated future world markets for minerals and mineral products.

Among the problems that the mineral industry in general will have to face in the future are increasing costs for labour and equipment, increasingly stringent regulations with respect to pollution control, and increasing costs for fossil fuels. While these problems are being met, the ore bodies being treated will be generally of lower grade and increasingly complex. Meeting these problems while remaining competitive with the rest of the world will require imagination and initiative on the part of all those concerned with the health of the mineral industry. Improved methods of concentration will be needed, especially in the technology of handling fine particles. Concentration and hydrometallurgical processes must be modified and combined to yield maximum overall efficiency, rather than be treated as separate operations as at present. The techniques of precipitate flotation, ion flotation, ion exchange and solvent extraction must be extended to new systems and the operations simplified. Improved methods of conducting pyrometallurgical operations must be developed, especially in electric furnace operations and continuous smelting. For some ores entirely new processes must be developed if the pollution control standards of the future are to be met. At the same time, the industry as a whole must move in the direction of instrumentation and the computerized control of its operations.

At the present time, research and development programs on mineral treatment problems are conducted in many universities, in various provincial and commercial laboratories, usually under industrial sponsorship, and by the industry itself. However, university programs are, and should be, related to the needs of individual students, and they frequently lack continuity and sometimes lack relevance to broad national needs. Programs sponsored by industries are naturally geared to private needs, and are almost invariably short-term. Thus there is a role for a federal agency that can keep the national interest as its principal concern, and that can afford to do the long-range research that will provide Canadian industry with the information it will need to deal in the best way with the processing problems of the future.

Activities:

Mines Branch activities undertaken to improve on methods of minerals and metals recovery are described under the following headings:

1.) Mineralogical research on ore minerals to determine their properties and their behaviour under known processing techniques, keeping in mind the possibility of developing new techniques based on improved knowledge.

Examples: Study of the effects of crystal structure of pyrrhotite on leaching behaviour; study of the stability of sphalerite in the presence of other sulphides at elevated temperatures; study of the surface properties of minerals, and the effects of chemical and physical (e. g., radiation) treatment of these properties.

2.) Research on beneficiation techniques that may be applied to individual ores, having regard to the further processing that is intended, seeking empirically the procedure that will result in the most effective overall process consistent with acceptable environmental degradation.

Examples: Laboratory and pilot plant investigation of the tantalum and cesium ores of Bernic Lake, Manitoba; of manganese ores of Woodstock, New Brunswick; of niobium ores of Oka, Quebec; of uranium ores of Elliot Lake, Ontario.

3.) Research on the treatment of metallic ores by chemical metallurgy, to yield useful products at acceptable cost and with acceptable environmental degradation.

Examples: Treatment of uranium ores by in situ leaching using bacterially-active solutions; treatment of uranium-bearing solutions by solvent extraction techniques to recover rare earths and thorium as by-products; extraction of copper, nickel and cobalt from concentrates by leaching processes.

4.) Research on the optimization of the processing of metallic ores, utilizing a mathematical model of the process to determine the most effective sequence of processes, and to determine the controls needed to achieve optimization.

Examples: Study of the crushing and grinding circuit of the Rio Algom mine at Elliot Lake, Ontario; of the Ecstall mine at Timmins, Ontario; of the Hudson Bay Mining and Smelting Company at Flin Flon, Manitoba.

5.) Research on corrosion problems in the mineral and metal processing industry, and the development of new and improved methods for protecting metals from corrosion.

Examples: Development of a new conversion coating to protect steel from corrosion by sulphur compounds; development of a technique for improving the corrosion resistance of chromium platings on steel; survey of corrosion problems in mines and mills.

6.) Provision of technical support for the research and development programs of the Mines Branch, including chemical, physical, mineralogical, and mechanical techniques.

Examples: Development of atomic absorption techniques for analysing slags; development of new methods for determining flotation reagent concentrations; development of methods for the study of metallurgical materials by DTA, TGA, and EGA; development of methods for the mineralogical examination of metallurgical products; construction of auxiliary equipment for an electric furnace plant.

Sub-Sub-Objective 2

"To ensure the most effective use of scarce mineral and metal resources"

Minerals once mined, processed, and put in use in the form of metals and other products, cannot be restored--though a fraction may be recovered through re-cycling. In this sense, all minerals are scarce, although some are more scarce than others at any given point in time. The changing character of the resource base results from the depletion of once abundant resources, the discovery and development of new resources and changes in technology that bring into use materials that had previously not been available, or were without value. With improved technology, a low-grade, uneconomic deposit of one generation may become a workable orebody of the next.

The effective use of resources will be, in part, determined by the amount and type available--this means the need to measure in physical terms the resources available, with due consideration being given to their amenability to processing and to the recovery of valuable constituents. Mineral resources cannot be viewed, however, solely in physical terms for it is also necessary to consider future demand or, as the economist describes it, future 'wants'. These wants have an important bearing on effective use, for the resources are only valuable insofar as they are wanted. There is thus an interplay between resources and wants that creates serious problems in estimating both. However, some quantitative estimates must be made because of the recurrent necessity for implementing public policy through the enactment of laws and other measures designed to promote and protect public interests. Effective use of resources is, then, largely a matter of weighing present and future needs, determining resources in terms of quantity, kind, and the technology required to process them, controlling the rate of exploitation accordingly, and eliminating all possible waste.

Because of the changing nature of both resources and wants with time, the quantitative measurements mentioned above become obsolete and require continued reassessment. It is primarily the future that poses the difficulty in making these assessments and it is on the future that science and technology are mainly focussed. Up to now technological progress has created new resources faster than man has destroyed or consumed old ones. The challenge, however, is rapidly becoming greater--present rather conservative estimates indicate that the rates of consumption of the more common metals will increase two to six times in the next twenty-five years. On the other hand, in the short term, we have situations that create serious international competitive pressures on our industry that science and technology must alleviate by finding new, or alternative, uses for materials in easy supply and by improving productivity.

In effect, then, in order to ensure the effective use of our minerals resources, we must use science and technology in addressing the problems of: identifying and measuring potential mineral resources; increasing the proportion of recoverable constituents in ores mined; recovering useful materials from waste products; ensuring that the more plentiful resources are substituted for those less plentiful; and, helping to meet the competitive pressures created by changing patterns of supply and demand in world trade through improved technology and innovation. In addition, the important aspect of predicting future needs and wants must be given attention--in part, an economic study but also a matter better considered under sub-sub-objective No. 6 in this paper "To ensure an awareness of trends and changes in the technology and use of minerals and metals".

Activities:

Mines Branch activities undertaken to achieve the most effective use of scarce mineral and metal resources are described under the following headings:

1.) Mineralogical research on low-grade or highly complex deposits of marginal economic interest to provide basic information of value in treatment and recovery methods.

Examples: The occurrence and distribution of nickel in Canada at levels in the range of 0.1% to 0.3%; disseminated copper-molybdenum deposits of the Highland Valley, B. C.; low-grade tin-tungsten-molybdenum deposits of south-east New Brunswick; the complex silver deposits of the Cobalt-Gowganda area.

2.) Research on analytical methods of evaluating ores, minerals and metals (part of the task of measuring resources).

Note: This is distinct from the support that our programs of the Mines Branch receive in analytical chemistry that, in total, account for about 50,000 determinations annually.

Examples: Overcoming problems related to the separation and determination of rare-earth elements; development of rapid and accurate methods of slag analyses for control purposes; matrix problems related to on-stream X-ray analyses; improving confidence limits in assaying for the platinum group metals; application of non-destructive methods of analyses for ores and minerals, e.g., neutron activation; and improving accuracy in determining trace elements at parts per million levels.

3.) Increasing the proportion of constituents recovered from the ores mined by increasing percentage recovery and by recovering minerals and metals that have hitherto been wasted.

Examples: Improving recovery of the very fine-grained zinc-copper ores of New Brunswick; the recovery of thorium and rare earths as by-products of uranium leaching; the recovery of gold at present being lost in the flotation of copper ores; the recovery of iron and nickel now being lost in asbestos plant tailings; and reclaiming fine hematite from gravity plants in iron ore concentration.

4.) Research on highly refractory or complex ores that have resisted efforts to develop, economically, a process for the recovery of the valuable constituents.

Examples: The ilmenite-hematite-magnetite ores of Ontario and Quebec; oxidised copper ores; and the Bird River chromite ores of Manitoba.

5.) Research on the recovery of useful materials from metallurgical waste, plant tailings and other industrial "garbage".

Examples: Research on the use of fly-ash from thermal power plants for use in light-weight aggregates and pozzolans; the use of iron oxide precipitator dust in clay brick manufacture; the use of residues of fertilizer plants to produce gypsum products; the recovery of vanadium from oil residues in petroleum refineries (with special application to the Alberta tar sand); the recovery and treatment of waste iron oxides from steel plants in ferrite (synthetic magnets) production.

6.) Recycling waste materials that represent the waste products of consumer and industrial consumption.

Examples: Processing used storage batteries for reclamation of the lead content; recovery of chromite from used foundry sand.

7.) Substitution of minerals and metals of one kind for another to conserve scarce or more costly resources.

Examples: Development of nickel alloys for use in coins to replace silver; research on sulphide semiconductors as possible replacement for the high cost semiconductor metals - silicon and germanium.

Sub-Sub-Objective 3

"To ensure the most effective conversion of industrial minerals to useful products"

Conversion of industrial minerals to useful products refers to conversion to intermediate stages or to saleable products where values added may be substantial.

The term "Industrial Minerals" includes non-metallic minerals and rocks, such as building and ornamental stone, clay, sand and gravel. The industrial minerals that contribute most significantly to the Canadian economy are: asbestos, crushed stone, clay and shale, gravel, gypsum, limestone and dolomite, potash, salt, sand, sulphur and silica. There are about eighty-six different industrial minerals known to occur in Canada, of which thirty-three are currently being exploited. An additional twenty-one have been examined and are, or have been, considered for potential use.

Industrial mineral deposits are not only different in a number of characteristics from metallic ore deposits but differ substantially within themselves, i.e., each industrial mineral deposit is unique and requires individual treatment in its development for the purpose of producing a useful commercial product. Because of the many interrelated factors involved in the development of industrial mineral deposits it is essential to have detailed knowledge of the mineralogical and chemical compositions at all stages of conversion. Because of properties that must be considered in their processing and use, no comprehensive treatment can be given of the many types of research and investigations underway. However, it is revealing to list some of the end uses for industrial minerals that are indicative of the large number and variety of problems that must be taken into consideration in their processing. These uses include such items as: aggregates, cement, asbestos products, chemicals, fillers, coaters, composites, and ceramics such as glass, refractories, abrasives, structural clay products, electrical porcelain, porcelain enamel, sanitary ware, wall and floor tile, electronic products, and pottery and dinnerware.

There are limited research facilities available in Canada for undertaking investigations into the beneficiation, treatment, and use, of most of our industrial minerals. This is especially true for ceramic products listed above, for which research facilities are practically non-existent. This is notwithstanding that industrial mineral production in Canada in 1968 amounted to about $1 billion. Such an economically important segment of industry is obviously in need of substantial technological support, a role the Mines Branch fills in pursuing the objective described above.

Activities:

The activities in this objective logically fall into two categories:

A) Beneficiation which is the first step towards conversion into a useful product. To achieve maximum contribution to the economy, priority is given to investigations that involve minerals of current economic value, particularly if the deposit occurs in an underdeveloped region (current work on Nova Scotian barite and celestite), and where expertise and facilities for knowledgeable research are not available in Canada. Examples of this work are:

1) Research and development of industrial minerals processing techniques and methods

Flotation problems are being solved by studying the effects of various flotation reagents and modifiers for separating industrial minerals from their impurities. For example, it was discovered at the Mines Branch that a biodegradable reagent could be successfully used for the recovery of barite and celestite in two plants near completion in Nova Scotia.

2) The development of new or improved processes for the beneficiation of Canadian industrial minerals

Frequently there may be only one deposit of a particular industrial mineral under development and consequently this involves close cooperation between the developing company and the Mines Branch. At present, beneficiating processes are being developed on fluorite, fluorite-barite, spodumene, barite, scheelite, marl, rare earths, talc and celestite.

B) The second activity involves the development of processes to convert industrial minerals raw materials into useful non-metallic products such as ceramics and structural products. In this activity new processing methods and equipment are investigated or existing processes are modified for converting raw materials into useful non-metallic materials. Examples of this work are as follows:

1) Improved processing of ceramic raw materials

R and D in the field of processing ceramics is extremely important in Canada because of the general lack of research facilities and the many difficult problems associated with heterogeneous ceramic raw materials such as clays. Current work includes the improvement of the thermal shock characteristics of ceramics; development of processing methods for conversion of clays and shales into clay products; and developing a Canadian source of high quality MgO for refractories.

2) Development of aggregates for construction

Current research is aimed at developing lightweight aggregates for lightweight concrete and for other structural products such as brick and tile. Continuous research and development is also being done on developing and improving ways of processing normal-weight aggregates from sand, stone, gravel, etc., so that they can be converted to durable aggregates suitable for Canadian conditions.

3) New methods of forming and firing

The work in this area is aimed at leading the development in Canada of new or improved methods of processing ceramics from the raw material to a finished product. Isostatic pressing and hot pressing are new techniques that are being investigated.

Sub-Sub-Objective 4

"To ensure the most efficient processing of metals and alloys"

The sub-sub-objective of ensuring the most efficient processing of metals and alloys is being pursued by means of two sub-activities. These are: "New Technology in Melting, Casting, and Solidification" and "New Technology in Forming and Fabrication".

Situation

Metals are useless until they are made available in some useful shape. This may be in form of a gear, shaft, or bracket, etc., that is part of a machine; or a beam, plate or sheet for use in structures, such as ships, buildings, bridges, pipe-lines, etc.

The processing system whereby raw metals are converted into useful products may be considered as being made up of a number of discrete but inter-related steps. These are melting, casting and solidification, hot working (e. g., forging, rolling, etc.) cold working (e. g., cold rolling) and welding. Metallurgical quality and manufacturing economy depend upon successful process control at each of these steps.

A small but rapidly growing portion of these products is produced from metal powders by a process that consolidates these powders without melting by the application of pressure and heat.

This, then, is what is meant by the term, "The Processing of Metals and Alloys". That segment of the Canadian economy concerned with the production of castings, forgings, structural shapes, etc., is dependent upon the successful application of the science and technology of the processes identified above. The Canadian metals processing industry has an annual production of about two billion dollars.

Many of these metallurgical processes will contaminate the environment unless special preventative steps are taken. Therefore, research on process modification to minimize environmental contamination is one of the more important aspects of this work.

Activities:

Typical examples of the research projects in these sub-activities are presented below.

Foundry Research

The quality of castings and efficiency of the casting process in terms of weight of finished castings vs. metal melted is, to a large extent, dependent upon the design of the mould gating system. Metal should flow into the mould without turbulence through completely filled gates. X-ray television fluoroscopy is being used to study the manner in which molten steel enters a mould cavity. These studies have shown that complete filling of the gating system does not occur unless the dimensions are somewhat less than those predicted by present theories. Other aspects of foundry operation related to casting quality are being studied.

Powder Metallurgy

The production of nickel powders and iron powders is growing rapidly in Canada. This production growth is in response to the expanding use of metal powder products by manufacturers, such as the automotive industry. The characteristics of metal powder are determined by the process by which they are made and this can influence the production techniques and quality of the resulting article. Nickel and iron powders from various Canadian manufacturers are being studied to determine the influence of their characteristics on these production techniques.

Environmental Improvement

One of the alloying constituents that has to be removed during the refining of secondary aluminum is magnesium. The conventional method of doing this is to bubble chlorine through the melt. The control of this process, in order to minimize the production of gaseous effluent, is being studied. The possibility of eliminating the use of gaseous chlorine is also being investigated.

Sub-Sub-Objective 5

"To ensure the most effective utilization of metal and mineral products"

The work in this sub-activity is not a mere cataloguing of properties but is concerned with understanding relationships between properties and composition so that the usefulness of mineral products and metals can be established. The term "Mineral Products" refers to non-metallic materials where the materials are industrial minerals or products made from them.

This work is designed to meet the future potential needs of the Canadian economy and defence for new and improved materials suitable for our environment and adapted to the use of our mineral resources.

Problems encountered in the utilization of metals and alloys can vary depending upon the application. It may be required to select the most suitable alloy for a specific application by evaluating the properties and characteristics such as: strength, corrosion resistance, weldability, formability, etc., of a number of candidate alloys. On the other hand, it may be necessary to modify an alloy or a group of alloys so that they would be satisfactory for use in some environment, such as the Canadian Arctic or severe marine conditions, etc.

Many industrial minerals or products made from them are imported because satisfactory means of utilizing Canadian deposits have not been developed, deposits are low grade, existing technology is inadequate, or because of the economics of transportation. Nonetheless, production value is increasing rapidly and in 1968 industrial minerals worth close to $1 billion were processed and made into such products as ceramics, construction materials, fillers, chemicals, etc., worth much more.

If increased utilization of minerals and metals is to occur, it is in the national interest to have a core of expertise with modern facilities at the federal level to help develop new or improved alloys and industrial mineral products through innovation in research. The alternative is to import the necessary raw materials and products, or to have development for organizations that can afford it done outside Canada.

Activities:

Typical examples of research carried on to meet this sub-sub-objective are described below.

1) Metals and Alloys for use in the Arctic

Alloys become embrittled under the conditions of extreme cold encountered in Canada's Arctic. A project has been undertaken to determine the relevant gaps in the technical knowledge on this subject which lies within the scope and capabilities of the Mines Branch.

2) High Strength Steels

The objective of this project is to evaluate the suitability of selected alloys for use in advanced structures of high efficiency in a variety of environments, and under conditions of dynamic shock loading.

The evaluation is based on studies of metallurgical and associated factors in the designing and fabricating of structures from steels having a yield strength in excess of 150,000 psi and alloys of a similar strength-to-weight ratio. Examples of such advanced structures are aircraft landing gear, foils for high speed hydrofoil craft, portable bridges, and deep submersibles.

3) Improvement of the Quality of Construction Materials of Mineral Origin

As part of the concept of obtaining concrete of consistently predictable properties ("normalized" concrete), new standards and new methods of predicting the strengths and other properties of concrete are being developed by inter-disciplinary research. The aim is to have durable concretes that will have consistent and reproducible properties suitable for Canadian conditions.

4) Research on Properties and Uses of Rocks, Minerals and Ceramics

Dielectric properties of ceramics, rocks and minerals, and such properties as thermal conductivity and thermal diffusivity of these materials at high temperature, are being studied to develop new Canadian products and techniques. Long-term projects on the properties of clays and asbestos are aimed at effective utilization of these materials.

5) Evaluation of Industrial Mineral Deposits

Generally this work involves a preliminary examination of samples submitted from industry, government or individuals. Frequently the samples are of a commodity such as bentonite having current economic interest and where no commercial laboratory in Canada has the expertise to evaluate them. As an example, the suitability of a Bearpaw formation bentonite from Saskatchewan for iron ore pelletizing is being investigated.

Sub-Sub-Objective 6

"To ensure a national awareness of trends and changes in the technology and use of minerals and metals"

In expanded form, this objective is aimed at ensuring that Canadians and Canadian industry dependent on mineral and metal markets will be able to take advantage of trends and changes in technology. The changes may result from scientific progress, from substitution of one material for another, from the uncertain demands of modern society, and even from competitive pressures exerted at an international level on mineral and metal markets. In large measure, research and development undertaken under this objective is concerned with the properties and behaviour of those materials (Materials Research) affected by the above-mentioned influences. Associated with this R and D, in fact, largely as a consequence of it, materials and their properties are under continuous review. The resulting accumulated knowledge is used in working towards the above objective and provides an essential source of information to technological forecasting activities that have become an integral part of the planning function of most organizations.

Technological change occurs in response to scientific discoveries, and to new social and economic needs. The resulting change makes new demands on materials, including minerals and metals, which can often cause awkward dislocations. These dislocations can be eased by the discovery of new sources of materials, by improved technology, and by more effective re-cycling and re-use of materials. New technology in materials has contributed indispensably to many new industries and applications--solid state devices, computers, lasers, nuclear power, titanium, and composite materials, to name a few.

We see, therefore, that problems and opportunities are continually presenting themselves in the field of materials research that represent a challenge to science and technology. In this connection, the government has an important role in providing information on what needs to be done, and why, and what the constraints are. It is only through knowledgeable scientists and engineers working with materials, in terms of research and application, that make it possible to perform this role.

It is evident, from what has been stated above, that this objective is primarily concerned with that part of the minerals and metals R and D program described in the introduction as "Materials Research". However, there is another aspect of awareness that might be mentioned here, although it is dealt with more fully in the Program Forecast Review--1972/73 of January 15, 1971. This is concerned with communications between the Mines Branch and other sectors, including industry, that are vital to the exchange of information and the development of successful liaison activities. These will be briefly referred to in the following section.

Activities:

Some examples of work carried out in pursuit of this subobjective are cited below, although no more than a few typical examples are given because of the great variety of work underway that might be considered under this general heading.

1.) Minerals and the Environment:

Production and use of minerals and metals have an important influence on the quality of the environment. Because of the rapidly changing social attitudes towards this important subject, the Minerals and Metals Technology Program must be concerned with it, as mentioned in the introduction. The interactions of materials produced in the processing of minerals and metals with the environment are complex, and scientific enquiry has only begun to provide parameters for investigation. The first task is, of course, to identify the objectionable or toxic materials and to determine their physical and economic consequences. The Mines

Branch has a large number of projects underway in the Minerals and Metals Technology Program that are directly related to this area, many of which have been described under the previous sub-objectives.

2.) Substitution:

Trends in substitution of one material for another have a very important impact on mineral and metal technology and use and so are dealt with here although the subject was briefly mentioned under Sub-objective No. 2. Our present level of technological sophistication permits an increase in the degree of interchangeability of materials so that more available materials can be substituted for those less available. Many examples may be cited from the past: plastics for metals in piping, aluminum for copper in transmission lines, the use of synthetic for natural fibres, and the substitution of nickel for silver in coins. The question of substitution is continuously in mind at the Mines Branch in the fields of metal use, structural materials, ceramics, and in a large variety of products of mineral origin.

3.) Standards:

To protect Canada's interests in international trade, and to assist industry within Canada, the development of standard methods of analyses and standard reference materials in undertaken. This work covers a variety of both chemical and physical methods of analyses and a wide variety of materials, including ores, minerals, metals, building materials, road materials, etc. This work is all done in close cooperation with both national and international standards associations.

4.) Powder Metallurgy:

The impact of powder metallurgy developments and their effects on forming procedures and metal processing make it essential that the Mines Branch be active in this area. These new developments can reduce pollution by eliminating high-temperature metal extraction and alloying and can contribute to the low-cost production of components because of the highly efficient utilization of materials.

5.) Electronic Materials:

Continuing developments are underway in the electronic ceramic field—considerable work has been done in the past on ferrites (magnetic materials) and piezoelectric materials for use as transducers.

6.) Continuous Casting:

In order to assist the galvanized sheet industry to meet competition from alternative coatings, the Mines Branch has conducted research on modifications to the galvanizing process to accommodate the particular needs of continuous cast-grade steel.

7.) Particulate Technology:

As an example of work in this field alumina particles suitable for ceramics substrates are being developed to replace imported materials. Here, as in other cases, using the latest characterizing techniques it is possible to demonstrate how different processing methods affect size, shape, and structures of particles used in, and which influence the properties of, ceramic bodies and other materials.

Information and Liaison:

The Minerals and Metals Technology Program generates a large body of new knowledge and provides an array of capabilities that are particularly relevant to industry. To ensure that good use is made of these resources, the Mines Branch has initiated and/or supported annual conferences, committees and the use of liaison officers to disseminate information and give needed assistance. Examples of such activities are:

Conference of Canadian Minerals Processors.
Canadian Uranium Producer's Metallurgical Committee.
Canadian Zinc and Lead Research Committee.
Canadian Mineral Analysts.

and participation in a large number of institutes and societies.

A - MINERAL PROCESSING DIVISION

SUB-ACTIVITY 1: IMPROVEMENTS IN MINERAL AND METAL EXTRACTION METHODS

Objective

"To improve methods in mineral and metal extraction".

(1) Situation and National Need

Paraphrasing the conclusions put forward in the Mines Branch position paper on Minerals and Metals Sub-Program, May 27, 1971, p. 6, the key statements that apply to the work of this division are: Among the problems that the mineral industry in general will have to face in the future are increasing costs, stringent pollution regulations, and ore bodies of lower grade and increasing complexity. A long list of projects requiring national concern is given. The point is made that there is a role for a federal agency to do long-range research which will provide Canadian industry with the information it will need to deal in the best way with the processing problems of the future. There are also roles for university research and industrial research.

(2) Planning Assumptions and Alternative Activities

Assuming, then, that the role of the federal agency is to do long-range research to provide industry with information to solve its problems, it then becomes necessary to identify the problems that affect rising costs, pollution regulations, and ore bodies of increasing difficulty.

(3) Criteria

At the same time, it is necessary to identify the aspects of those problems that are (from a national point of view) best solved by industry, what contribution of knowledge will be required by industry from the universities, and what problems and information can best be supplied by the federal agency.

(4) Preferred Courses of Action

These criteria applied to the many alternative activities that might be carried out by the Mines Branch have resulted in the following activities selected by this division for long-term research:

a) Research on beneficiation techniques that may be applied to ores, particularly unique deposits where often no technology has been developed.
b) Research on the optimization of the processing of metallic ores by applying scientific metallurgical and operating principles.
c) Research on the handling of fine materials.

(5) Project Titles and Technical Objectives

a) Research on Beneficiation Techniques that may be Applied to Ores, Particularly Unique Deposits where often no Technology has been Developed

The projects under this sub-activity have the objective of utilization of known mineral resources that have been prevented from development by mineral processing problems. There must be a definite reason which makes utilization of the resource a desirable objective in accordance with national economic or social policies.

(1) A current problem is the development of a viable concentration process for the tungsten-bismuth-tin-molybdenum deposits in S. E. New Brunswick. It is considered that this project would remain undeveloped without federal aid since the companies involved have spent over $8 million in the past 10 years on metallurgical research at industrial, contract, provincial and university establishments without much success.

b) Research on the Optimization of the Processing of Metallic Ores by Applying Scientific Metallurgical and Operating Principles

The current project under this activity is the investigation of means of optimizing the relationship between requirements for mineral concentration by flotation and the preparation processes such as grinding. The initial goal is the most advantageous size distribution for flotation recovery and product grade and the controlling principles for producing such a size distribution in the grinding process.

c) Research on the Handling of Fine Materials

The immediate goal of this project is to increase the capability of liquid-solid separation of fine materials with a size range from 0. 043 millimeters downward. Cost is not the only problem. The acceptability of the product for the succeeding metallurgical stage is also important. Also, liquid-solid separation is a major problem in anti-pollution technology.

(6) Projected Costs and Scheduling

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
a) Research on Beneficiation Techniques---No Technology has been Developed					
Professionals	2	2	2	18,000	108,000
Technicians	2 1/2	2 1/2	2 1/2	8,000	60,000
Overhead					30,000
					198,000
b) Research on Optimization of Processing of Metallic Ores.....					
Professionals	2	2	2	19,000	114,000
Technicians	3	3	3	8,000	72,000
Overhead					45,000
					231,000
c) Research on Handling of Fine Materials					
Professionals	1	2	2	16,000	80,000
Technicians	1 1/2	2 1/2	2 1/2	8,000	60,000
Overhead					15,000
					155,000
Grand Total					
Professionals	5	6	6		302,000
Technicians	7	8	8		192,000
Overhead					90,000
					584,000

(7) Benefits

a) Employment for up to 100 workers directly, indirectly a new town in New Brunswick, and exportable metal products with a conservative value of $15 million.

b) In treating a base metal (Cu-Pb-Zn) ore, flotation and grinding account for 43% of the direct operating costs. On an average ore a saving of 5% by process optimization would result in a saving of $0.08 per ton. As 115 million tons of metallic ore are processed annually in Canada, the cost benefit of even a 1% improvement would be appreciable to the national economy and would repay the effort.

c) More efficient means of dewatering will result in alleviating the impact of effluent restrictions on industries. All of the 115 million tons referred to in b) above must be dewatered to some degree before disposal, if only to recycle the process water. Also, costs of mineral processing will be lowered.

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SUB-ACTIVITY 2: UTILIZATION OF METALLIC MINERAL RESOURCES

Objective

"To ensure the most effective use of scarce mineral and metal resources".

(1) Situation and National Need

In the Mines Branch position paper on Minerals and Metals Sub-Program, p. 9, it is stated that to ensure the effective use of mineral resources, we must use science and technology in identifying and measuring potential mineral resources; increasing the proportion of recoverable constituents in ores mined; recovering useful materials from waste products; and improving technology and innovation to meet competitive pressures in changing world markets.

(2) Planning Assumption and Alternatives

Planning assumptions are the same as outlined under Sub-Activity 1, with the difference that industry cannot be expected, over the short term, to spend much money on conservation if it interferes with profit. Therefore, as the conservation of resources by improved technology is in the national interest for the future, the federal government must either carry out the necessary research into new technology required or improve regulations to enforce high recoveries; and, if the latter, do sufficient research to establish realistic goals.

(3) Criteria

The choice of activities to accomplish the objective must be made with the aim of producing the most economic and social benefit with the given research resources. A prerequisite is sufficient research experience and knowledge of mineral processing technology to make an intelligent decision as to what must or can be done by industry, universities and government facilities.

(4) Preferred Courses of Action

Preferred courses of action are listed below, applying the criteria above to the presently known resources, technology, industrial needs, performance, capability and research activity.

a) Increasing the proportion of constituents recovered from the ores mined by increasing percentage recovery and by recovering minerals and metals that have hitherto been wasted.
b) Research on highly refractory or complex ores that have resisted efforts to develop, economically, a process for the recovery of the valuable constituents.
c) Research on the recovery and recycling of useful materials from metallurgical plant wastes and waste materials resulting from consumer and industrial consumption.

(5) Project Titles and Technical Objectives

a) Increasing the Proportion of Constituents Recovered from Ores Mined

Current goals are improvement in two areas:

1) Development of methods for recovering nickel-iron from tailings of the asbestos mines in the Eastern Township of Quebec.

2) Gravity concentration and flotation research to recover part of the hematite iron ore presently being wasted as fine tailing from the three iron ore producing plants in the Labrador-Quebec area.

b) Research on Highly Refractory or Complex Ores that have Resisted Efforts to Develop an Economic Process for Recovery

(This activity has somewhat the same objectives as Activity a) under Sub-Activity 1, with the difference that here a general class of mineral resources of geological significance is under investigation rather than known deposits. The benefits, therefore, affect resource development by encouraging exploration and mining activity.)

Current projects include:

1) Investigation of concentration and extraction processes for the oxide-copper deposits occurring in British Columbia. These minerals also occur in sulphide ore bodies presently being mined and the oxide copper recoveries are very low.

2) Investigation of processes for concentration of the large sulphide-bearing iron deposits of N. W. Ontario. These deposits contain a high percentage of sulphides which adds to the cost of iron extraction and produces intolerable air pollution using present methods. The sulphide minerals contain valuable base metals which can help offset costs of processing.

3) Investigation of processes for concentration of molybdenum from the high-talc ores of N. W. Quebec. The presence of talc, which cannot be economically separated from the molybdenum, has resulted in cessation of molybdenum mining in this region.

c) Research on the Recovery and Recycling of Useful Materials from Wastes

1) One of the main projects is a study of methods of reducing the amount of water returned to the natural streams by concentration plant operations. The ideal goal would be to recycle all water.

2) Application of mineral processing methods to waste recovery and recycling. Waste materials frequently occur in industrial wastes because of physical properties. Mineral processing methods can frequently be employed to utilize these properties to advantage for recovery without resorting to expensive chemical processing.

3) Conversion of solid mineral and metallurgical wastes to useful products. The technical objectives of this project are:

- (i) To develop raw materials for non-metallic products such as fillers, chemicals, ceramics and building products from mineral and metallurgical wastes.
- (ii) To develop useful non-metallic products such as ceramics and building materials from mineral and metallurgical wastes.

(6) Projected Costs and Scheduling

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
a) Increasing the Proportion of Constituents Recovered from the Ores Mined					
Professionals	2	2	2	18,000	108,000
Technicians	4	4	4	8,000	96,000
Overhead					90,000
					294,000
b) Research on Highly Refractory or Complex Ores					
Professionals	3	3	3	18,000	162,000
Technicians	5 1/2	5 1/2	5 1/2	8,000	132,000
Overhead					90,000
					384,000
c) Research on Recovery of Useful Materials from Wastes					
Professionals	3	3	3		156,000
Technicians	3	3	3		78,000
Overhead					91,500
					425,500

(7) Benefits

a) Benefits to the Canadian economy including the conservation of resources estimated at:

1) In the asbestos industry 9,000 tons/year of nickel assuming that, on a conservative estimate, 25% of the present tailings will be treated. Value of this nickel at present prices is estimated at $20 million.

2) In the iron producing area of Quebec-Labrador, 1 1/2 million tons of iron ore pellets per year based on an estimated recovery of 75% of the present losses (F.O.B. (St. Lawrence ports) value $16.20/ton).

b) Production from large copper deposits not being developed now and increased production from present mines.

Establishing of the W. Ontario deposits as an iron ore reserve for the future and a possible source of iron for the prairie region.

Renewal of the mining industry in the N.W. Quebec region which, due to the closure of gold and molybdenum mines, is an economically depressed area receiving substantial financial assistance from the federal government.

c) Lowered pollution of streams by mines and lowered cost of tailings retreatment.

Conservation of resources and savings in imported materials through recovery of useful materials otherwise wasted.

The contributions to the objectives of the national policy are considerable but a dollar value cannot be placed on the social benefits.

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SUB-ACTIVITY 3: DETERMINING CHANGES IN MINERALS TECHNOLOGY AND UTILIZATION

Objective

"To ensure a national awareness of trends and changes in the technology and use of minerals and metals".

(1) Situation and Alternative Criteria

The Branch position paper clearly states that the preferred course of action to accomplish this objective is materials research, specifically: substitution of materials, powder metallurgy, electronic materials, continuous casting, and particulate technology as applied to ceramic manufacture.

It should be pointed out here that, with the possible exception of continuous casting, all of the activities must be raw materials based and there are many problems in obtaining suitable materials. For example, the major problem with iron powder metallurgy is its high cost which severely limits uses regardless of powder or product quality. The only ways to reduce the cost are to improve the starting material and to improve the powder production process. Therefore, it seems that research and study to this end would be justified.

(2) Courses of Action

However, the position paper does list two courses of action in which this division will participate, a) information and liaison, through active participation in industrial and technological committees and conferences and b) international participation in scientific and technological organizations.

Without going further into the situation and national need, which have been adequately covered in the position paper, this division's activities are listed below.

a) Information and Liaison

(1) Liaison with N. R. C. and Department of Industry, Trade and Commerce on research assistance projects under the IRAP programs of NRC and the PAIT and IRDIA programs of IT&C. This liaison takes the form of consultation during the assessment of proposals, and as liaison officers with the projects in progress to give guidance to the industry and to assess progress for the government agencies.

(2) Liaison with university research takes several forms:

1) Assessment of university requests for assistance under this Department's research grant plan and recommendations to the Advisory Board. This requires liaison with the projects while in progress to assist and advise and to evaluate progress and project eligibility for renewal.

2) Assistance to universities that have limited facilities and knowledge of industrial application. This is particularly true with post-graduate research projects which are usually very short term, from one to three years. Also, assistance is required in seminars and short courses, even regular courses at times, to enable universities to carry out their role of research awareness effectively. This latter takes the form of guest lectures and professional advice both to professors and students.

3) **Assistance to universities in lecture and text book preparation. To keep these up-to-date and pertinent to industrial and national needs, liaison with universities and assistance is necessary.**

(3) Industrial advice, assistance and liaison is provided through participation in the Canadian Mineral Processors, a committee representing the mineral processing industry of Canada; the Canadian Institute of Mining and Metallurgy; the American Institute of Mining and Metallurgy, which contributes directly and indirectly to Canadian industrial knowledge; and local conferences and organization meetings whose input into industrial technological progress warrants assistance.

(4) Liaison with industry to identify trends and needs, normally by field trips to the mining plants, usually at five year intervals.

(5) Preparing reviews of technology and scientific papers for publication resulting from the expertise developed by research activities.

b) International Participation in Scientific and Technological Organizations

The division participates currently in,

(1) International Mineral Processing Congress,
(2) Commonwealth Mineral Processing Congress,
(3) International Standards Organization (ISO), Under the ISO activities are included representation on committees dealing with iron ore specifications and sieving methods, and technical and organizational participation in the Canadian Advisory Committee. This is organized under the Canadian Standards Organization.
(4) CIDA. This takes the form of advice on selection of experts going overseas, advice on technical feasibility of projects and training of CIDA sponsored visitors to Canada.
(5) Colombo Plan trainees.

(3) Projected Costs and Scheduling

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
a) and b)					
Professionals*	2	2	2	18,000	108,000
Technicians	1/2	1/2	1/2	8,000	12,000
Overhead					30,000
					150,000

*Note: These totals are a pooling of fractional inputs (and costs) by all professionals in the Sub-Division since all professionals contribute part of their time to the activities, particularly to the industrial and university liaison which ensures leadership in technology.

SUB-ACTIVITY 4: CONVERSION OF INDUSTRIAL MINERALS

Objective

"To ensure the most effective conversion of industrial minerals to useful products".

(1) Situation

Conversion of industrial minerals to useful products refers to conversion to intermediate stages or to saleable products where values added may be substantial. The Sub-Activity having the above objectives is entitled "develop technology for processing industrial minerals into useful raw materials and into non-metallic materials such as ceramics and building materials".

The term "Industrial Minerals" includes non-metallic minerals and rocks, such as building and ornamental stone, clay, sand and gravel. The industrial minerals that contribute most significantly to the Canadian economy are: asbestos, crushed stone, clay and shale, gravel, gypsum, limestone and dolomite, potash, salt, sand, sulphur and silica. There are about eighty-six different industrial minerals known to occur in Canada, of which thirty-three are currently being exploited. An additional twenty-one have been examined and are, or have been, considered for potential use.

Industrial mineral deposits are not only different in a number of characteristics from metallic ore deposits but differ substantially within themselves, i.e., each industrial mineral deposit is unique and requires individual treatment in its development for the purpose of producing a useful commercial product. Because of the many interrelated factors involved in the development of industrial mineral deposits it is essential to have detailed knowledge of the mineralogical and chemical compositions at all stages of conversion. Because of the large number of industrial minerals, and the variety of characteristics and properties that must be considered in their processing and use, no comprehensive treatment can be given of the many types of research and investigations underway. However, it is revealing to list some of the end uses for industrial minerals that are indicative of the large number and variety of problems that must be taken into consideration in their processing. These uses include such items as: aggregates, cement, asbestos products, chemicals, fillers, coaters, composites, and ceramics such as glass, refractories, abrasives, structural clay products, electrical porcelain, porcelain enamel, sanitary ware, wall and floor tile, electronic products, and pottery and dinnerware.

(2) Planning Assumptions

There are limited research facilities available in Canada for undertaking investigations into the beneficiation, treatment, and use, of most of our industrial minerals. This is especially true for ceramic products listed above, for which research facilities are practically non-existent. This is notwithstanding that industrial mineral production in Canada in 1968 amounted to about $1 billion. Such an economically important segment of industry is obviously in need of substantial technological support, a role that the Mines Branch fills in pursuing the objective described above.

(3) Relation to Other Mines Branch Studies

The work is related to and sometimes part of research on the properties of non-metallic materials and industrial minerals and to the development of non-metallic materials from the beneficiation and utilization of mineral wastes. Emphasis is placed on beneficiation and processing. This work on industrial minerals and non-metallic materials is frequently related to such fields as beneficiation of metallic ores, and mineral science studies by Mineral Sciences Division.

(4) National Need

Of more than 80 industrial minerals known to exist in Canada, slightly less than half are produced commercially. Many industrial minerals are imported because satisfactory beneficiation and processing methods have not been developed and because of the scarcity of many Canadian industries within economical transportation. Longer freight hauls become possible as methods of transport improve and if newer and more efficient processes are developed. As these factors occur, a greater variety of domestic raw materials for establishment of Canadian secondary industries will be available.

(5) Alternative National Policy

It is possible to discontinue broad federal expertise in this area and allow provincial facilities, industry and private facilities to cope with research and development of industrial mineral processes. Unfortunately, much of the work would likely be done in other countries or indifferently because of the lack of research facilities, particularly in such fields as ceramics and the use of minerals and rocks as aggregates for construction where many small companies do not have research facilities.

(6) Criteria

It is necessary for Canada to take the lead in developing technology for processing its industrial minerals. A laboratory at the federal level will provide a core of expertise in this field, a research capability with the ability of moving into an activity in strength, and a means of developing new and improved methods of processing the countries non-metallic resources into useful products. In addition to urgent current problems research for future requirements in Canada is necessary.

(7) Preferred Course of Action

The preferred course of action is to provide a national laboratory facility with highly trained scientific personnel to carry out research on new processes and process methods for Canadian industrial minerals.

(8) Project Titles and Technical Objectives

Projects a) and b) below deal with beneficiation, which is the first step towards conversion into a useful product. In projects c), d) and e), new processing methods and equipment are investigated or existing processes are modified for converting raw materials into useful non-metallic materials. To achieve maximum contribution to the economy, priority is given to studies that involve minerals of current economic value, particularly if they occur in an underdeveloped region.

a) The Development of Industrial Minerals Processing Techniques and Methods

The immediate objectives are:

(i) To solve flotation problems by studying the effect of various flotation reagents and modifiers for separating industrial minerals from their impurities.

(ii) To find new materials to efficiently float industrial minerals.

(iii) To study the use of special equipment for the recovery or removal of weakly magnetic materials and for the separation of industrial minerals by electronic sorting.

b) The Development of New or Improved Processes for the Beneficiation of Canadian Industrial Minerals

The objective of this project is to develop beneficiation processes on specific industrial minerals. Frequently there may be only one deposit of a particular industrial mineral under development and this involves close cooperation between the developing company and the Mines Branch. The work may result in new mines and plants, and the improvement of processes in existing plants. At present beneficiating processes are being developed on fluorite, fluorite-barite, spodumene, barite, scheelite, marl, rare earths, talc and celestite.

c) Improved Processing of Ceramic Raw Materials

The objective of this project is to develop ways of processing Canadian raw materials into useful ceramics such as clay products, refractories and whitewares. Research is done on processing such minerals as kyanite, magnesite, kaolin, fireclay, common clay, shale, nepheline syenite, talc, pyrophyllite and spodumene.

d) Development of Aggregates for Construction

The objectives are:

(i) To assist with the development of lightweight, normal-weight, and heavyweight aggregates for construction under Canadian climatic conditions and from Canadian materials.

(ii) To study the effect of various Canadian mineral aggregates on the properties of concrete and other construction materials.

e) New Methods of Forming and Firing

The objective of this work is to lead the development in Canada of new or improved methods of processing ceramics from the raw material to a ceramic product. Isostatic pressing and hot pressing are new techniques that are being investigated.

f) A Study of the Relationship Between the Morphology of Particulates and the Microstructure of Fired Ceramics

The objective of this project is to demonstrate by use of ultra-modern characterization techniques how different processing methods affect size, shape, and structures of particles used in, and which influence the properties of, ceramic bodies and materials. At present Canadian alumina particles are being studied so that they may be modified to make them suitable for ceramic substrates to replace imported raw materials.

+(9) Projected Costs and Scheduling

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
a) Processing Techniques and Methods					
Professionals	2.5	2.5	3.5**	18,000	153,000
Technicians	2	3**	3	8,500	68,000
*Overhead					70,000
					291,000
b) Beneficiation of Canadian Industrial Minerals					
Professionals	1.5	1.5	1.5	18,000	81,000
Technicians	4	4	4	8,250	99,000
*Overhead					70,000
					250,000
c) Improved Processing of Ceramic Raw Materials					
Professionals	2.5	2.5	2.5	18,000	135,000
Technicians	2	2	2	9,500	57,000
*Overhead					90,000
					282,000
d) Aggregates for Construction					
Professionals	1.5	1.5	1.5	16,000	72,000
Technicians	1	1	1	8,000	24,000
*Overhead					46,500
					142,500
e) New Methods of Forming and Firing					
Professionals	1	1	1	19,000	57,000
Technicians	1	1	1	9,000	27,000
*Overhead					40,500
					124,500
f) Morphology of Particulates					
Professionals	0.5	0.5	1	16,000	32,000
Technicians	1	1	1	9,000	27,000
*Overhead					21,000
					80,000

+ Includes ore mineralogy

* Does not include costs of buildings and outside services.

** Additional positions for priority projects.

(10) Benefits

(i) Processes are developed for beneficiation and processing of Canadian industrial minerals.

(ii) Production quantity, quality and value of Canada's industrial mineral production is increased through research and the consequent assistance in the establishment of new mines and plants.

(iii) Secondary industry is stimulated by the development of new processes for the conversion of industrial minerals into ceramics and construction materials of mineral origin.

(iv) An important benefit as part of, or as a consequence of, this activity is the expertise developed by the scientific staff in the field of beneficiation and processing of industrial minerals into useful products. This staff provides expert information to industry, universities and governments in their fields.

The output of research cannot always be measured in dollars and cents, nor can the provision of technical advice to the industrial minerals industry be properly evaluated. Examples of this work are: a process developed at the Mines Branch for recovery of barite is being used in 1971 by International Mogul Mines in the final stages of development by pilot plant in Nova Scotia prior to establishing a plant to produce $4.0 million of fluorite and barite annually from Cape Breton ore. Kaiser Resources have commenced production of celestite (a scarce mineral used for TV colour tubes) in 1971 from Cape Breton ore. Thermal shock resistant bodies using Canadian lithium minerals in comination with Canadian and imported clays were developed for pottery and sewer pipe. Research on the upgrading of an Edmonton lightweight aggregate raw material has resulted in continued production of clay lightweight aggregate in that area. Continuous studies are being made on sources of Canadian MgO for refractories and chemicals. Flotation problems are being solved by studying the effects of various flotation reagents and modifiers for separating industrial minerals from their impurities. Emphasis is being placed on biodegradable reagents.

The expenditure of the funds shown in (9) is a small investment for Canada to make in the $5 billion mining industry, about $1.0 billion of which is the value of industrial minerals (structural and non-metallic). These raw materials are used in the ceramic industry (a production in Canada of over $400 million in 1966); the $13 billion construction industry; and the huge chemical and allied industries using industrial minerals as fillers, coaters, carriers, chemicals, etc.

(11) References

(a) Research and Development of Industrial Mineral Processing Techniques and Methods

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2. Kent, G. A., "Recovery of High Purity Magnesium Oxide and Calcium Oxide from Magnesite and Calcite Ores", U. S. Patent 3, 411, 880, November 1968.

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5. Wyman, R. A., "The Floatability of 21 Non-Metallic Minerals", Mines Branch Technical Bulletin TB 108, January 1969.

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(b) The Development of New or Improved Processes for the Beneficiation of Canadian Industrial Minerals

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2. Hartman, F. H. and Wyman, R. A., "Beneficiation of Celestite from Cape Breton, N. S.", Mines Branch Investigation Report IR 71-20, March 1971.

(c) Improved Processing of Ceramic Raw Materials

1. Brady, J. G. and Bell, K. E., "Some Methods of Investigating Firing Problems", Journal of the Canadian Ceramic Society, 34, 9-20, 1965.

2. Bell, K. E., "Suitability for Brick-Making of a Shale from Lantz, Nova Scotia", Mines Branch Investigation Report IR 70-37, 1970.

(d) Development of Aggregates for Construction

1. Hanes, F. E., "Sand Manufacturing from Ottawa Valley Limestone", Mines Branch Investigation Report IR 67-19, August 1967.

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3. Wilson, H. S., "Comparison of Clays from Edmonton, Alberta, for Lightweight Aggregate", Mines Branch Investigation Report IR 69-3, January 1969.

4. Wilson, H. S., "Properties of Fired Clay for Use as Concrete Aggregate", Mines Branch Investigation Report IR 71-12, February 1971.

(e) New Methods of Forming and Firing

1. Svikis, V. D., "Dense Lithium Fluoride for Gamma-Ray-Free Neutrons Shielding", Mines Branch Research Report R 119, February 1964.

2. Bell, K. E., "Isostatic Pressing of High-Calcined Bodies", Journal of the Canadian Ceramic Society, Vol. 37, 1968.

3. Mirkovich, V. V. and Wheat, T. A., "Use of Liquid Nitrogen in Spray Freezing", Bulletin American Ceramic Society, Vol. 49, No. 8, August 1970, pp. 724-725.

SUB-ACTIVITY 5: UTILIZATION OF INDUSTRIAL MINERALS

Objective

"To ensure the most effective utilization of industrial mineral deposits".

(1) Situation

The work is not a mere cataloguing of properties but is concerned with understanding relationships between properties and composition so that the usefulness of mineral products can be established. The term "Mineral Products" refers to non-metallic materials where the materials are industrial minerals or products made from them.

This work is designed to meet the future potential needs of the Canadian economy and defence for new and improved materials suitable for our environment and adapted to the use of our mineral resources.

Many industrial minerals or products made from them are imported because satisfactory means of utilizing Canadian deposits have not been developed, deposits are low grade, existing technology is inadequate, or because of the economics of transportation. Nonetheless production value is increasing rapidly and in 1969 industrial minerals worth close to $1 billion were processed and made into such products as ceramics, construction materials, fillers, chemicals, etc., worth much more. Problems encountered in the utilization of industrial minerals for non-metallic materials are varied. Generally, it is necessary to develop products having properties for specific conditions, many of them peculiar to our Canadian environment. Industry generally consists of small companies without research facilities, or of large corporations with research facilities and expertise in another country. Thus there is a national scarcity of scientific facilities and expertise in this area.

(2) Planning Assumptions

Increased sophistication, advancing technology, and a severe environment are creating demands for non-metallic materials with special properties. Because of various factors including large numbers of small companies lacking research facilities, Canadian industry will not keep up with trends in utilization without assistance. In addition to utilization needs under Canadian conditions, the need to manufacture more competitive products for export requires more active research on Canadian non-metallic materials. It is assumed that the work must be supported by first class mineralogists and equipment.

(3) Relation to Other Mines Branch Studies

The work is closely allied with Sub-Activity 4. This work deals with the examination and beneficiation of raw materials through to the development of a finished non-metallic material such as glass, clay products, refractories, building products, etc.

The work on beneficiation is related to the work of the Metallic Minerals Sub-Division, Mineral Processing Division, and to the work of the Mineral Sciences Division. Support is required from analytical laboratories of Mineral Sciences and from Technical Services Division.

(4) National Need

This has been discussed previously and an important point may be repeated here "resources are created by research". If secondary industries for non-metallic materials are to be created in Canada, it is necessary to develop sources of raw materials and sources of products utilizing our raw materials. Scarcity of research facilities in certain of the ceramic groups and in the construction industry in Canada only helps to emphasize the need for a National Laboratory to assist with the development and utilization of non-metallic materials through research.

(5) Alternative National Policy

Provincial agencies, industry and universities may cope successfully with individual problems. The work on utilization of non-metallic minerals and products requires a laboratory with expertise in the fields of ceramics, construction materials of mineral origin and other industrial minerals products. In general, expertise in these fields is lacking in all areas of Canada. The small number of materials science laboratories have few experts in non-metallic materials. Laboratories in industry are few in number because of the inability of small companies to provide research facilities and to tackle a research problem in strength. In this field there is no satisfactory alternative to a laboratory equipped to deal with national problems.

(6) Criteria

It is necessary to carry out research on the properties of industrial minerals and their products so that effective use will be made of Canada's non-metallic mineral resources.

(7) Preferred Course of Action

The preferred course of action to ensure effective use of Canada's non-metallic mineral resources is to carry out research on them at the federal level.

(8) Project Titles and Technical Objectives

a) Improvement of the Quality of Construction Materials of Mineral Origin

As part of the concept of obtaining concrete of consistently predictable properties ("normalized" concrete), new standards and new methods of predicting the strength and other properties of concrete are being developed by inter-disciplinary research. The objective is to have durable concretes that will have consistent and reproducible properties suitable for Canadian conditions.

b) Research on Properties and Uses of Rocks, Minerals and Ceramics

The objective is to develop new non-metallic products, and techniques suitable for Canadian conditions and our economy. Dielectric and thermal properties of ceramics, rocks and minerals are being studied. The effect of particle size, shape and composition on properties of non-metallic materials is being investigated. Long-term projects on the properties of clays and asbestos are aimed at effective utilization of these materials.

c) Evaluation of Industrial Minerals Deposits and Products

The objectives are: (1) to assist with the development of industrial mineral deposits by determining properties of samples from deposits not in production. Generally this work involves a preliminary examination of samples submitted from industry, government or individuals. Frequently, the samples are of a commodity such as bentonite having current economic interest and where no commercial laboratory in Canada has the expertise to evaluate them, and (2) to determine and evaluate the properties of non-metallic materials. This work is done only in special circumstances related to special problems in industry and government (e.g. for National Revenue - Customs and National Defence - refractories, electronic ceramics, whitewares, etc.).

+(9) Projected Costs and Scheduling

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
a) Quality of Construction Materials of Mineral Origin					
Professionals	4	4	4	18,000	216,000
Technicians	3**	3	3	9,000	81,000
*Overhead					92,000
					389,000
b) Properties and Uses of Rocks, Minerals and Ceramics					
Professionals	6	6	7**	18,000	342,000
Technicians	2.5	3.5**	4.5**	8,500	89,250
*Overhead					173,000
					604,250
c) Evaluation of Industrial Mineral Deposits and Products					
Professionals	1.5	1.5	1.5	16,000	72,000
Technicians	0.5	0.5	0.5	8,000	12,000
*Overhead					41,000
					125,000
Grand Total					
Professionals	11.5	11.5	12.5		630,000
Technicians	6	7	8		182,250
*Overhead					306,000
					1,118,250

+Includes Ore Mineralogy

*Does not include costs of buildings and outside services.

**Extra positions for important projects and to correct existing serious lack of staff.

(10) Benefits

(i) The quality of non-metallic materials in Canada is improved. For example:

(a) Development of new methods of quality control for concrete - for example, an accelerated strength test for concrete developed at the Mines Branch has reduced the evaluating time for compressive strength determinations from 28 to 1 day. The work has permitted a more economical mix design and better quality control. Out of an annual value of $1 billion, concrete having a value of about $37 million does not meet specifications. Even if the new test detects 1/4 of this there would be an annual saving of about $9 million.

(b) Research on the durability of concrete under different environmental conditions has been of benefit to large users of concrete such as Quebec Hydro to adjust their methods to suit Canadian conditions.

(c) Research on the relationship of composition of ceramic clays and shales to properties, and on the properties, preparation and uses of asbestos fibre, for example, is advancing technology in these fields.

(ii) Assistance to the development of new secondary industry is provided and existing industry stimulated by the development of new materials or techniques. For example, a small plant at Lindsay, Ontario, Almax Ceramic Industries Limited, was recently established for the manufacture of piezoelectric ceramics using a patented process developed at the Mines Branch.

(iii) Preliminary information on the properties of industrial minerals from deposits having a potential for development is being provided for industry, private individuals and companies. For example, current work on bentonite from the Bearpaw formation in southern Saskatchewan.

(iv) In certain non-routine and special cases, properties of non-metallic materials such as ceramics and building materials are determined to assist in such areas as customs classification or to explain unexpected behaviour of a material in service. Expertise in the field of non-metallic materials is essential because interpretation is impossible without prior knowledge. For example, work in cooperation with the Department of National Health and Welfare on allowable tolerances of soluble lead in glazed ceramic food utensils and qualification of refractories for DND.

(v) The research staff working on the development of industrial mineral deposits and non-metallic materials are experts in such fields as non-metallic minerals, ceramics, and building materials. They provide expert consulting advice on the technology, properties and utilization of these materials to industry, governments, universities and consultants.

B - EXTRACTION METALLURGY DIVISION

SUMMARY

This program, planning and budgeting statement covers the Extraction Metallurgy Division activities planned for the 3-year period of April 1972 to March 1975 which relate to the Minerals and Metals Technology sub-objective of the department's Mineral and Energy Resources Program. It has been prepared on the assumption that it will be read in conjunction with the preceding Position Paper prepared which describes the position of the Mines Branch with regard to this sub-objective of the department. The purpose, background and scope of the general activity of the Mines Branch regarding the objective is adequately covered by the Position Paper.

The Minerals and Metals Technology Sub-Objective exists to "ensure the most effective conversion and use of minerals and metals". Almost 65 per cent of the dollar resources of the Extraction Metallurgy Division will be devoted to pursuing this objective during the forecast period. The EMD projects which comprise the major activity come under the following three sub-activities:

a) development of improved methods for minerals and metals recovery at an approximate annual cost of $600, 000 for each of the next 3 years.
b) the development of methods which will ensure that scarce metal and mineral resources are used effectively at an annual cost of $70, 000 for each of the next 3 years.
c) the efforts directed towards ensuring an awareness of trends and changes in the technology and use of minerals and metals at an annual cost of $87, 000 for each of the next 3 years.

SUB-ACTIVITY 1: MINERALS AND METALS EXTRACTION

Of the several sub-activities which contribute to the Minerals and Metals Technology Activity of the Mines Branch, the Extraction Metallurgy Division has projects in the following:

a) The development of technology for the treatment of metallic ores by chemical metallurgy.
b) The application of advanced systems methods to metallurgical processes.
c) The development of corrosion control techniques aimed at reducing the costs of operation in mining and metallurgical industries.

d) The provision of analytical, mineralogical and mathematical support services for Sub-Activity No. 1, "Minerals and Metals Extraction".

(i) Situation

Canada has rich resources of copper, nickel, lead and zinc in the form of sulphide deposits the treatment of which generally involves smelting methods (1). Many of these deposits are small and capable of sustaining mining and milling operations only on a scale of one or two thousand tons of ore per day producing a hundred tons of concentrate per day for shipment to a smelter (2). Other deposits, though large, have a complex composition which often makes it difficult to produce concentrates compatible with smelters designed for specific metals and high-grade concentrates. The metal values contained in ores of this latter type are not, therefore, efficiently recovered by flotation followed by smelting (3). Furthermore, smelting any of these sulphide concentrates releases gaseous sulphur dioxide to the atmosphere, a situation which is under fire as a threat to the environment. As a result of all this, new hydrometallurgically-based processes are being sought for recovering the common base metals from sulphide concentrates, both as a means of reducing pollution and providing a means for treating the more complex concentrates.

The larger base-metal smelting companies are working on this type of process development, but they consider their results to be proprietory and, of course, are devoting their efforts to their own specific problems. The smaller companies, which in many cases have complex deposits, find it difficult to finance an individual process-development program which might yield a concentrate-treatment process that could be financed and operated by a small producer (4). At the same time high smelter charges, the threat of cancelled smelter contracts, and pressure by some provincial governments to force the processing of concentrates in Canada are combining to place many producers or potential producers in a difficult position (5, 6). This is particularly significant where the deposits are in economically depressed areas of the country.

The situation as it applies to the less common and precious metals, which include such metals as tantalum, bismuth, molybdenum, tungsten, niobium and rare earths, is in many ways similar to that described above for the common base metals. Further treatment of the raw concentrates of these metals involves in some cases the production of gaseous sulphur dioxide, while in other cases the concentrates are complex and too low-grade to be marketable. At the same time the state of the technology is such that it is not possible to design an alternative process without additional process development studies being done. The producers of concentrates of this type are usually small companies with limited funds for this type of development study. Where marketable raw concentrates of these metals are produced, they are usually sold abroad for further treatment. Where the complex nature of the deposit precludes the production of a marketable raw concentrate, the deposit has in the past remained undeveloped.

There is a growing awareness in the metallurgical industries of the potential advantages in the application of modern instrumentation and control techniques to metallurgical processes. The larger companies are developing their own in-house expertise in this area, but smaller companies although interested often cannot afford to do this, and at the present time there is a shortage of consultants with the necessary background in both metallurgical processes and control technology (7).

A recent survey has shown that the mining and metallurgical industry is spending millions of dollars a year on replacing equipment, utilities and buildings damaged by corrosion. The general attitude has been that it is cheaper to replace damage caused by corrosion than to prevent it.

(2) Planning Assumptions

a) Efficient utilization of Canada's copper, nickel, lead and zinc resources, as well as those of the less common metals, will depend on the development of processes suitable for treating the more complex ores. These processes should be capable of being built and operated profitably on a small scale, and capable of converting the sulphide content of these ores to elemental sulphur or sulphate rather than sulphur dioxide. The need for such processes will increase rather than decrease during the forecast period, while the situation regarding industry's efforts in this area will not change appreciably.

b) Processes of the type described in a) will only be developed by a multi-disciplined, well equipped team of process-oriented researchers having as its objective the development of a fully integrated, viable process.

c) If a viable, integrated process is demonstrated on a bench scale, industry will take the initiative from that point (9).

d) During the forecast period industry will become more interested in applying modern mathematical and computer techniques to metallurgical testing and process development, while the number of people skilled in this area will not increase as fast as the demand (10, 11, 12).

e) The increasing cost of operating supplies and materials will make the mining industry much more aware of the need for corrosion control in the future.

(3) Relation to Other Mines Branch Studies

Because the projects that comprise this activity are done in the context of an integrated process, the hydrometallurgical process work must be assessed and optimized in the light of process development studies in ore beneficiation and pyrometallurgy.

(4) National Needs

If the country is to develop an efficient resource management policy, it is essential that new technology be developed in advance of obvious need. This will make it possible to treat a wide range of ores, both low-grade and complex, with high efficiency in any part of the country, to produce metal or metal compounds rather than raw concentrates, and with minimum effect on the environment. Hydrometallurgy and related technology offer a good possibility of meeting this need.

(5) Alternatives

The following alternatives are available to the Canadian government for the encouragement of the process studies, relevant to non-ferrous metal ores, which are needed to maintain the process technology at a level which will make sound resource management and energy policies meaningful.

a) Encourage industry through some form of government financial support to conduct the process studies required to meet future national needs.

b) Have the work done in universities or in independent research organizations under government contract.

c) Limit government financial support, and assume that industry will develop the needed technology as it is required largely at its own expense.

d) Support a well-equipped, multi-disciplined government laboratory charged with the responsibility of developing technology 5 to 10 years ahead of its need by industry in meeting national goals.

(6) Criteria

The most suitable courses of action are those which will ensure that process technology is always such that the government's programs for such things as resource management and environmental protection are not hampered by incomplete or unknown technology. In addition the approaches taken should ensure that all aspects of a given problem are considered.

(7) Preferred Courses of Action

a) Support those industries large enough to have an effective process development group through grants or tax incentives in conducting work relevant to their individual, immediate interests.

b) Support a government process development laboratory to conduct the work not being done by the larger companies, but which appears to be needed to meet foreseeable national needs.

c) The universities and research organizations could do directed, specific, unit process studies in support of a complete process study being done under alternatives a) or b).

(8) Project Titles and Technical Objectives

a) Hydrometallurgical Treatment of the Common Base Metal Sulphide Ores

The object of the current work in this project is the development of a process for the hydrometallurgical treatment of complex copper - nickel - cobalt - iron sulphide concentrates. The processes under study include oxidation-pressure leaching to produce elemental sulphur and metal sulphates in solution; hydrochloric acid leaching of nickel-bearing pyrrhotite with acid recycle; ferric chloride leaching with reagent recycle; various methods for recovering the metal values from solution such as cementation, precipitation, and solvent extraction processes for dewatering and neutralizing the waste materials and related beneficiation steps. In addition, leaching at atmospheric pressure is being studied. Other studies include the required analytical development work, and mineralogical research related to the process studies (13, 14, 15, 16).

The objectives of the study are the demonstration on a bench scale of a complete process and the development of the data necessary to allow for the design of a larger scale plant.

b) Hydrometallurgical Treatment for the Recovery of the Less Common and Precious Metals

The object of the current work in this project is to develop a hydrometallurgical process that will recover bismuth, and indium from a complex, but large and potentially valuable ore body in New Brunswick. The process will include a leaching step plus solution treatment processes.

Although the immediate objective is to develop a process for this particular ore body, the information and data will be useful and applicable to other situations. Another part of this project relates to the development of a process to recover rare earths from the Elliot Lake uranium ores.

c) The Application of Control, Mathematical Modelling, and Optimization Techniques to Metallurgical Processes

An approach that can be used to sample a complex grinding classification circuit, and then analyse the data to produce a mathematical simulation of the physical circuit for subsequent study and manipulation, is in an advanced stage of development (10, 11, 12). A similar study related to solvent extraction columns is also underway. In addition the development of on-line methods of analysis is being studied (17).

The objectives of these projects are:

(i) to place the Mines Branch in a position where it is able to inform industry of the precise method of beginning and conducting a mathematical modelling program. The type of help is available only to a limited extent in the private sector at present.

(ii) to develop on-line monitoring instruments to suit the special needs of the metallurgical industry. Because this has been, traditionally, a limited market, instrument manufacturers are usually slow to respond to a need in this area.

d) Development of Methods to Reduce Corrosion Costs in Mine and Metallurgical Plants

The objective of this project is to determine if the cost of maintenance and operating supplies in grinding and flotation operations can be reduced through corrosion control. In the past these costs have been attributed to wear, but there is evidence that at least some of the results observed are due to corrosion. In another phase of this project the effect of gaseous elemental sulphur in various metals is being assessed to determine what metals may be used in sulphur recovery processes (17).

(9) Projected Costs and Scheduling

a) Hydrometallurgical Treatment of the Common Base Metal Sulphide Ores

	Man Years per Year			Cost per Man Years	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	5.25	5.25	5.25	15,000	236,250
Technicians	3.4	3.4	3.4	8,000	81,600
Plant, service and overhead					194,150
					512,000

b) Hydrometallurgical Treatment for the Recovery of the Less Common and Precious Metals

	Man Years per Year			Cost per Man Years	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	2.25	2.25	2.25	15,000	101,250
Technicians	1.35	1.35	1.35	8,000	32,400
Plant, service and overhead					82,350
					216,000

c) The Application of Control, Mathematical Modelling and Optimization Techniques to Metallurgical Operations

	Man Years per Year			Cost per Man Years	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	3.2	3.2	3.2	15,000	144,000
Technicians	1.0	1.0	1.0	8,000	24,000
Plant, service and overhead					99,000
					267,000

d) Development of Methods to Reduce Corrosion Costs in Mine and Metallurgical Plants

	Man Years per Year			Cost per Man Years	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	3.0	3.0	3.0	15,000	135,000
Technicians	1.2	1.2	1.2	8,000	28,800
Plant, service and overhead					85,200
					249,000

e) The Provision of Analytical, Mineralogical and Mathematical Support Services

	Man Years per Year			Cost per Man Years	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	4.4	4.4	4.4	15,000	198,000
Technicians	7.5	7.5	7.5	8,000	180,000
Plant, service and overhead					141,000
					519,000

f) Total for Minerals and Metals Extraction Sub-Activity (Section a) to e) above)

	Man Years per Year			Cost per Man Years	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	18.1	18.1	18.1	15,000	814,500
Technicians	14.45	14.45	14.45	8,000	346,800
Plant, service and overhead					601,700
					1,763,000

(10) Benefits

It is very difficult to place a realistic dollar value on the benefits that could accrue from the successful completion of the projects described in this sub-activity.

It is sure that a healthy, developing base metal mining and metallurgy industry will depend on processes other than smelter-based operations. If Canadian production of copper, nickel, lead and zinc is to keep pace with world consumption, the value of these metals produced in Canada must increase at the rate of 100 million dollars annually. Compared to this, the 0.25 million dollars/year that will be spent on the development of process innovation that will aid the industry as a whole to reach this production objective would appear to be a modest, if not inadequate, amount. Also, benefits such as potential patent royalties and the development of technology with less pollution control problems are to be considered.

(11) References

1. B. W. MacKenzie, "Nickel - Canada and the World", Mineral Resources Division, Mineral Report No. 16, Dept. of Energy, Mines and Resources, Ottawa, 1968.

2. Metal and Industrial Mineral Mines and Processing Plants in Canada, 1968, Mineral Resources Branch, Operator's List 2, Dept. of Energy, Mines and Resources, 1970.

3. The Northern Miner, July 1, 1971, re Chromex Nickel Mining.

4, 5, 6, 7 - Private communications since Jan. 1, 1971.

8. G. R. Hoey and W. Dingley, "Corrosion Control in Canadian Sulphide Mines and Mills", The Canadian Mining & Metallurgical Bulletin, Vol. 64, No. 709, p. 62, 1971.

9. W. A. Gow and G. H. Ritcey, Extraction Metallurgy Division Visit Memorandum EMV 69-12. Visit to discuss use of solvent extraction process developed and patented in Ottawa by International Nickel Co. of Canada Limited. Process is being designed into new INCO plant.

10, 11, 12 - F. J. Kelly, Extraction Metallurgy Division Visit Memoranda EMV 69-49, EMV 71-8, EMV 71-11. Meetings with industrial organization to provide advice and arrange cooperative programs on process control and modelling.

13. J. A. Vezina, "Acid Pressure Leaching and Pentlandite - Chalcopyrite - Pyrrhotite Concentrate", Mines Branch Technical Bulletin TB 129, Dept. of Energy, Mines and Resources, Ottawa, Dec. 1970.

14. G. M. Ritcey and B. H. Lucas, "Separation of Nickel and Cobalt by Liquid-Liquid Extraction from Ammoniacal Solutions", Extraction Metallurgy Division Author's Memorandum EMA 71-4, 1971. Paper presented to 1971 Annual Meeting of the C. I. M. M.

15. D. J. MacKinnon, T. R. Ingraham and R. Kirby, "Copper Cementation on Nickel Discs", Extraction Metallurgy Division Author's Memorandum EMA 70-18, Sept. 1970. For publication in Canadian Metallurgical Quarterly.

16. J. E. Dutrizac and R. J. C. MacDonald, "The Effect of Sodium Chloride Under Simulated Dump Leaching Conditions", Extraction Metallurgy Division Author's Memorandum EMA 71-1, Jan. 1971. For publication in the Transactions of the AIME.

17. K. W. Downes, Progress Report, Extraction Metallurgy Division Internal Report EMP 71-1, March 1971.

SUB-ACTIVITY 2: EFFECTIVE USE OF SCARCE MINERAL AND METAL RESOURCES

(1) Situation

Recent estimates of world consumption of the common metals forecast that, by the year 2000, the demand for these metals will increase by factors ranging from two to eight, depending on the metal being considered. Although vigorous mineral exploration programs and improved extraction technology has resulted in supply keeping up with demand up to now, even greater efforts will be required in the future if the world's metal requirements are to be satisfied. From this point of view then all our metal resources must be considered to be "scarce".

Consequently, we must be sure that metals are used as effectively as possible and this will necessitate programs aimed at identifying, measuring and assessing the overall economic feasibility of potential resources; recovering useful materials from waste products; increasing the recovery of values from mixed ore; and ensuring that the metals are used as efficiently as possible.

At present and for the balance of the forecast period the major contribution of the EMD to this sub-activity is work designed to improve the efficiencies of electroplating techniques by using less metal or cheaper plating metals. In addition, an integral part of the Minerals and Metals Extraction Sub-Activity, which was discussed earlier, involves studies aimed at maximum possible recovery of all metal and other values present in a particular ore. An example of this is the project, discussed under Sub-Activity No. 1, on rare earth and thorium recovery from the Elliot Lake ores. Whether projects of this type (and these can develop rapidly due to changing market demand or user technology) belong under Sub-Activity No. 1 or this Sub-Activity is open to argument.

Regarding the electroplating industry in Canada, it is valued at 50-80 million dollars a year, and is comprised of companies who produce electroplated components by known technology using imported electroplating chemicals. Essentially no research, other than what is going on in the EMD (1, 2, 3), is being done in electroplating in Canada. This is in spite of the fact that R & D could lead to metal conservation, as well as better plating techniques using better plating solutions, which in turn could result in the development of an important secondary industry with export potential.

(2) Planning Assumptions

a) The electroplating industry in Canada will continue to increase and, unless Canadian R & D efforts produce better technology, the volume of secondary metal products that will have to be imported will increase accordingly.

b) It would be difficult to encourage industrial R & D activity since the industry is not R & D oriented. In addition it would take some time, certainly beyond the forecast period, to build up an effective R & D electroplating expertise in Canadian industry and universities.

c) It is to the national interest to ensure that some R & D in the electroplating field is done in Canada.

(3) Relation to Other Mines Branch Studies

As discussed in the section on the situation regarding electroplating in Canada, there is almost no development work being directed towards electroplating technology except that being done in the EMD. Consequently the EMD electroplating projects do not merge, or overlap other Mines Branch projects. However, the electrochemical aspects of electroplating are relevant to electro-winning or electro-refinery technology. Consequently, the group in the EMD working on the electroplating projects could be called upon to consult and assist in development projects in the field of electro-metallurgical innovation.

(4) National Need

It is generally accepted by both government and the general public that one of Canada's greatest needs is an expanded secondary industry. Electroplating is already a significant secondary industry in Canada, but it could be even more important if it developed new technology so that both its products and know-how were of international interest.

(5) Alternatives

a) Continue to support the development of new electroplating technology at the Mines Branch.

b) Encourage industry, university and other research organizations to conduct work aimed at the development of new electroplating technology by grants and liaison.

(6) Criteria

Development work should be done mainly in those fields of electroplating where the volume of industrial production is high, such as chromium plating; or where the public safety is concerned (3).

(7) Preferred Courses of Action

The only course of action at the present time is to continue the electroplating work at the Mines Branch. It would take several years to encourage other research organizations to develop effective programs.

(8) Project Titles and Technical Objectives

a) Electroplating Development

Studies are being conducted in an attempt to develop methods for use in chromium electroplating which will allow the use of a thinner nickel undercoat or the elimination of the nickel altogether. Success in this project would reduce the cost of chromium electroplating and conserve nickel. Other studies are being conducted in an effort to reduce the required thickness of zinc coatings on steel. In another project a method has been developed for improving the electrodeposition of bismuth or copper. This development is important to the electronics industry since previously published information did not provide an acceptable solution to the problem.

(9) Projected Costs and Scheduling

	Man Years per Year			Cost per	Total Cost
	72/73	73/74	74/75	Man Years	for 3 Years
a) Electroplating Development					
Professionals	1.9	1.9	1.9	15,000	85,500
Technicians	2.1	2.1	2.1	8,000	49,600
Plant, service and overhead					61,900
					207,000

(10) Benefits

As has been mentioned earlier, the electroplating industry in Canada has an annual value of 50 to 80 million dollars. If the development work done at the Mines Branch resulted in even a 1 per cent increase per year in the volume of the business, the benefit/cost ratio would be about 10.

(11) References

Since there is no real R & D effort in electroplating being done in Canada other than what is being done at the Mines Branch, the only references to work being done are Mines Branch reports. The situation regarding electroplating R & D is known to Mines Branch personnel through communication and liaison with the industry.

1. J. C. Saiddington and G. R. Hoey, "Improvement in Chromium Plating from a Low Ratio Sulphate Bath", Extraction Metallurgy Division Author's Memorandum EMA 70-3. (For publication in Plating).

2. Can. Patent 859,116 (Dec. 22, 1970) "Stable Silver Cyanide Plating Baths". W. Dingley, J. Bednar and R. R. Rogers. U. S. Patent applied for.

3. Can. Patent 855,189 (Nov. 3, 1970) "Plating High Strength Steel Without Hydrogen Embrittlement". W. Dingley, J. Bednar and R. R. Rogers. U. S. Patent applied for.

SUB-ACTIVITY 3: ENSURING AN AWARENESS OF TRENDS AND CHANGES IN TECHNOLOGY

(1) Situation

The extraction metallurgy segment of the Canadian mineral industry has in the past depended heavily on conventional pyrometallurgical processes for the primary recovery of metals, except say for zinc and gold. Because of the conventional nature of the processes, the industry has tended to be self-sufficient in its requirements for technical process and related information. However, in recent years there has been considerable new development and application of hydrometallurgical processes for nickel-copper ores, and for uranium and less common metals, which has led to a realization that hydrometallurgical technology developed for one phase of the mineral industry is often applicable after suitable modification to other phases of the industry. This has been shown by the requirements to the Mines Branch for information and assistance both for the original development and also for the subsequent exploration of the application of the technology to other parts of the industry.

Extraction metallurgy processing technologies are being studied through applied and basic research by the operating companies, by the universities and by commercial and government metallurgical research organizations to meet changing industry conditions such as markets, primary material sources, environmental requirements and overall economic factors (1). Information on these industry trends and changes becomes available to a more or less degree in many forms, and full assessment of the effects on any particular segment of the industry can be difficult to assess. This is complicated by the less than fully effective communication between the various sectors of the industry and between industry, universities and research organizations, as recently reported (2). The Mines Branch with its specialists in extraction metallurgy and its own research programs in extraction metallurgy has played an important role in bridging the communications gap and has the potential for greater service in this area.

Other government departments charged with administering control and assistance programs in the mineral industry require the assistance of the extraction metallurgy specialists of the Mines Branch for guidance and advice in connection with programs in this field of extraction metallurgy.

(2) Planning Assumptions

It is anticipated that the need for specialized information services in extraction metallurgy will increase, particularly in connection with newly available process technology, with meeting new market specifications, and also with increased emphasis on control of plant effluents and protection of the environment. It thus will be necessary to continue the information services in extraction metallurgy now being performed and to adopt measures to make them more effective. The other technical communication measures such as informal technical gatherings of specialists of the metallurgical industry and direct contact with metallurgical staffs will also have to be continued and extended where possible.

(3) Relation to Other Mines Branch Studies

The Extraction Metallurgy Division, with its metallurgical specialists and its information service in extraction metallurgy, complements other sections of the Mines Branch in this sub-activity, such as the Mining Information Centre and the Mineral Processing Division, in serving the needs of the Canadian mineral industry for technical information and providing advice and guidance when requested.

(4) National Need

To compete in the highly competitive world markets for mineral products, the Canadian producers must utilize the optimum production systems in all phases of their operations including the metallurgical phases. It is important then that Canadian producers be kept aware of new developments in extraction metallurgy processes so that full advantage can be taken of them. Parts of the Canadian industry have only limited staff resources for locating and following technical developments elsewhere so there is a need for central sources of technical information to serve the segments of the industry lacking these facilities.

To be fully effective, the central information source must be of such a calibre that the needs of the industry enquirer can be analysed and the most applicable technical information selected to meet the enquirer's needs. The Extraction Metallurgy Division, with its expert staff of long association with the extraction metallurgy segment of the mineral industry and its information bank in extraction metallurgy technology, is in an unique position to offer useful information and advice to the industry.

It has been observed that the metallurgical staffs of many Canadian producers lack technical liaison with their contemporaries, partly because of their plant locations and also because existing facilities are not designed to serve them. To meet the needs of the metallurgists of the industry, an informal liaison service is provided, and also by means of industry-government organizations, such as the Canadian Mineral Processors, Canadian Mineral Analysts, Canadian Uranium Producers' Metallurgical Committee, direct contact between industry metallurgists is effectively obtained. Such liaison activities also provide valuable feed-back to the Mines Branch to increase the relevance of the Mines Branch activities.

(5) Alternatives

If the activity directed to the sub-sub-objective named earlier is not carried out, smaller units of the mineral industry would have to develop their own information services, with consequent expensive duplication, or else operate with only very limited background information support. Much of the useful contact between industry metallurgists and the government metallurgical laboratories would be lost, and feed-back, useful for program guidance, would be greatly reduced. Other government departments would likely have to operate with much less technical guidance than now being afforded to them.

(6) Criteria

The basic consideration in an effective awareness service is the availability in one place of many of the technical information sources from which information of particular value to the extraction metallurgy industry can be referenced, together with metallurgical specialists who can recognize and assess the value of such information. From such circumstances an information service that can keep the industry aware of the trends and changing technology and use of minerals can be provided. Also useful advice and guidance can be provided as requested by units of the industry to meet their metallurgical situations.

(7) Preferred Course of Action

The preferred course of action is to continue to serve the mineral industry by working to ensure that changes and trends in extraction metallurgy technology are followed, analysed as to their relative importance and brought to the attention of the industry as requested. Also advice and guidance to and in the solution of metallurgical difficulties of the industry can be provided, based on the skill of the metallurgical specialists of the division, coupled with the available reference technical information on related metallurgical processes. Consultative assistance in the field of extraction metallurgy should be continued to other government departments to aid them in their support programs in the mineral industry.

(8) Project Titles and Technical Objectives

a) Information Consultation and Advice in Extraction Metallurgy to the Mineral Industry

The objectives of this activity are (1) to ensure that the section of the mineral industry concerned with extraction metallurgy is kept abreast with new metallurgical technology and is served in its needs for suitable pertinent technical information and advice in regards to current operations or planning new operations; (2) to facilitate effective channels of technical communication between the metallurgists of the industry; (3) to assist in keeping the Mines Branch informed on the trends of technological progress in extraction metallurgy in the mineral industry and elsewhere.

b) Information, Consultation and Advice in Extraction Metallurgy to Other Government Departments

The objective of this activity is to provide metallurgical consultation services and expertise to other government departments charged with administrating programs in the extraction metallurgy section of the mineral industry.

(9) Projected Costs and Scheduling

	Man Years per Year			Cost per Man Years	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	3.75	3.75	3.75	15,000	168,750
Technicians	--	--	--	8,000	--
Plant, service and overhead					128,250
					297,000

(10) Benefits

The input of the sub-activity to the EMD contribution to the Minerals and Metals Technology Activity is important because of its value in the planning, coordinating and controlling of the projects comprising this activity. It is not possible to put a meaningful dollar value on the benefits occurring from the projects in this sub-activity since the measures of its success are the benefits arising from the process development projects which are the major part of the Minerals and Metals Technology Activity.

(11) References

1. News Item, "Chemical Route to Copper", Chemical Engineering, April 20, 1970.

2. Recent Survey of the Research Effort of the Mining Industry on Behalf of National Advisory Committee.

C - PHYSICAL METALLURGY DIVISION

OBJECTIVE

> "To ensure the most effective conversion and use of minerals and metals".

BACKGROUND AND SCOPE

The Physical Metallurgy Division of the Mines Branch contributes to this objective by pursuing work having the following sub-activities:

1. Processing of Metals and Alloys.
2. Utilization of Metals and Alloys.

The work of these two sub-activities is of direct technical assistance to the Canadian metal-working industry which accounts for over 40% of all manufacturing activity in Canada. Since the Canadian metal-working industry is the sole domestic customer for the metal-resource industry, it is therefore evident that the operations of the Physical Metallurgy Division promote the use of Canadian metal resources in a very direct way.

The objective noted above is pursued by:

a) applied research and development on ways to improve processing operations of metals and alloys in order to provide technical guidance to industry on ways and means to increase operational efficiency;
b) applied research and development on the characteristics of metals and alloys and how the factors of environment, composition and metallurgical condition influence these characteristics. This type of work is necessary to promote the most effective utilization of our metal products.

SUB-ACTIVITY 1: PROCESSING OF METALS AND ALLOYS

(1) Situation

The metallic ore resources of Canada constitute a natural supply of metals such as iron, zinc, copper, nickel, etc. These ores must be converted into semi-fabricated products such as casting sheet and strip, rod and bar, etc., which find their ultimate application in automobiles, consumer appliances, machinery of all sorts, and engineering structures (such as bridges, buildings and pipelines).

The type of processing operations that are carried out to accomplish these ends may consist of melting, alloying, casting, rolling, extrusion forging and powder metallurgy, together with welding, pressing and forming, and any other operations that result in a change in configuration.

Alloys must be produced to meet rigid specifications of strength, formability, weldability, corrosion resistance, etc., to meet the requirements of subsequent manufacturing operations and to permit the economical design and fabrication of the end item. Since the manner in which all processing operations are conducted can have a major influence on the characteristics of alloys and therefore on the serviceability of the end product, these processing operations and their effects on the characteristics of the alloys being processed must be thoroughly understood. The work described below is being undertaken to develop this knowledge within well prescribed limits set by an awareness of the most important Canadian needs and the limitations imposed by available staff and facilities.

(2) Relation to Other Mines Branch Activities

The Processing of Metals and Alloys Sub-Activity is one of several sub-activities of the Mines Branch that, taken in sequence, deal with Canada's mineral and metal resources commencing with the treatment of the ore and ending with non-metallic materials and metals and alloys of industrial and engineering usefulness that have been derived from these ores.

(3) Alternatives

In order to achieve the objective, two types of projects should be undertaken. These are projects of an applied nature and also projects of a fundamental nature.

Applied projects have the immediate objective of applying basic scientific principles to the modification and/or improvement of the various processing operations used to convert metals into alloys and shapes of industrial usefulness.

Fundamental projects have the immediate objective of establishing the basic scientific principles involved in these processing operations.

(4) Criteria

In keeping with the policy of the Mines Branch, work done in the Physical Metallurgy Division should contribute to the Canadian resource industries* either by direct technical support or indirectly by providing such support to the Canadian metal working industry, which represents the immediate customer of the Canadian resource industry.

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* "Industry" in this context refers to a broad industrial activity; not to an individual corporate body.

(5) Preferred Course of Action

In order to fulfil the above criteria the Physical Metallurgy Division of the Mines Branch has undertaken projects of an applied nature and has elected, where possible, to concentrate its efforts on work with long term objectives that could not be justified by private industry because there would be no immediate return or because facilities and personnel are lacking. In selecting these objectives, particular attention is paid to such typically Canadian conditions as extreme cold, and small scale widely dispersed processing operations.

(6) Project Titles and Technical Objectives

a) New Technology in Melting, Casting and Solidification

The usual first stage in processing metal from the primary product into useful alloys and configurations is to melt it. In the molten condition, undesirable impurities are removed, and alloying additions are made in order to achieve a specific and pre-determined composition. The effectiveness of the refining operation and the efficiency of utilization of the alloying additions are both dependent upon the conditions under which this melting operation is carried out.

The metal is next cast into a mould to give it the configuration required. All aspects of the construction of the mould are extremely important and must be carefully controlled in order to obtain efficient conversion of the molten alloy into the desired solid configurations.

After the molten metal is cast into the mould it solidifies. This is a physical process that is responsive to control. If it is not adequately controlled, defective castings can be produced or the potential properties of the alloy may not be achieved.

In order to study effectively the problems involved in the processing operations identified above, the work has been organized into three sub-projects. These are:

1) Oxygen in Liquid Metals.
2) Foundry Research.
3) Melting and Casting of Metals and Alloys.

1) Oxygen in Liquid Metals

The objectives of this sub-project are:

(i) to further refine the designs of the solid-electrolyte probe element of the oxygen probe used to determine the oxygen content of molten steel.

(ii) using this probe, to carry out research on the control of oxygen content of molten steel and other molten metals in order that operations such as the steel-making process may be better understood and carried out in a more economical manner.

2) Foundry Research

The quality of castings and the efficiency of the casting process in terms of weight of finished castings vs total weight of metal melted is dependent upon the materials used to make the mould, the techniques used to produce the mould, the design of the casting from the point of view of solidification and the design of the system by which molten metal flows into the mould.

The objectives of the Foundry Research sub-project are therefore:

(i) to advance the technology of foundry mould design from the point of view of solidification within the mould and also from the point of view of flow of metal into the mould.

(ii) to develop new and improved materials and techniques for producing foundry moulds. These improvements could be based on such factors as cost of the moulding operation, cost of cleaning castings after removal from the mould, surface finish and dimensional accuracy of the casting.

3) Melting and Casting of Metals and Alloys

This sub-project is concerned with the operations of melting and casting and the influence of these operations on the characteristics of the resultant alloy.

For example, such factors as maximum temperature, holding time in the molten condition, sequence of making various alloying additions, can have a very important effect on the resultant properties.

The continuous casting operation, when applied to specific metals, must be modified in terms of mould design, protective slags, pouring basins, etc., to suit the specific metal being cast.

It is possible to control the solidification process of certain types of alloys so that a fibrous structure is obtained.

The objectives of this sub-project are, therefore:

(i) to study the parameters of the various melting, alloying and casting operations used in the processing of metals and alloys that have a bearing on the economics of these operations and also affect the characteristics of the resulting product.

(ii) to develop modified and improved techniques for carrying out these operations.

b) New Technology in Forming and Fabrication

Most of the alloys that are used in consumer and industrial products are processed into their final form by one or more of a series of operations that involve hot forming, such as forging, rolling and extrusion; cold forming, welding, and the application of surface protective coatings, e. g. zinc to steel (galvanizing).

In addition to these conventional forming operations, the powder metallurgy process is becoming increasingly important. This is a process whereby metal or alloy powders are directly consolidated by pressure, heat and subsequent forging or rolling into finished metallurgical products.

This project is organized to study the metallurgical aspects of the processing operations identified above. This project has been broken down into the following "sub-projects":

1) Powder Metallurgy
2) Welding
3) Galvanizing
4) Metal Forming

1) Powder Metallurgy

The selection of topics of research in this sub-project has been based on an awareness of the needs of the Canadian powder metallurgy industry.

For example, metal powders are produced by a wide variety of techniques and from a number of different source materials. The behaviour of these powders during conversion to useful alloys and shapes by pressure, heat, rolling, forging, etc., is to a considerable extent determined by the physical characteristics of the bulk powder used.

It is the objective of this sub-project to characterize Canadian produced metal powders, and in particular iron and nickel powders, in order that these Canadian produced powders can compete more successfully on the world market as a result of an increased knowledge of the details of their characterization and the factors which control their behaviour.

A second objective is to study the factors involved in processing these powders by pressure, heat and forging, into finished shapes of high structural integrity that will be the equivalent of conventional forgings produced by the melting-casting-forging route with all its associated metal wastage.

2) Welding

The objectives of the welding sub-project may be expressed in the following general terms.

(i) To evaluate welding processes and to ascertain their scope and limitations.
(ii) To evaluate weldability tests, i. e., to evaluate procedures for determining the characteristics and properties of welded joints and to study the factors affecting these characteristics and properties.

This work is being carried on in order to improve the standard of welding in Industry and the Armed Forces in Canada by providing:

(i) Information on the selection of welding processes suitable for specified construction situations, e. g., the selection of a suitable welding process for a new steel being considered for ship hulls by the Canadian Navy and also for large commercial structures by the Canadian construction and fabrication industries.
(ii) Information on weldability tests to steel manufacturers to assist in the development of new and improved steels. To provide similar information to steel fabricators to assist them in constructing safer, stronger, and more reliable structures.
(iii) Quantitative data and methods for evaluating and predicting heat flow in welds as a function of the type of joint, thickness of the steel in the joint, and power input. This is intended to result in computer programs that can be used to select the best combination of joint design and welding procedure for specific design situations.

Work concerned with weldability and welding procedures for specific alloys is done as part of material characterization studies carried out under the project for the Evaluation and Improvement of Metals and Alloys (see Sub.-A. 2). Work in the Welding sub-project that is described above is concerned primarily with the welding process itself.

3) Galvanizing

From the point of view of economics and effectiveness, galvanizing is one of the best ways to protect steel from atmospheric corrosion. The ability of steel to accept a zinc coating can be changed by modifications to the composition of the steel, steel mill practice and also to the galvanizing process itself.

It is therefore essential to understand the manner in which these changes can influence the nature and effectiveness of the protective zinc coating in order that the galvanizing process may be suitably modified to suit a specific type of steel.

The immediate objective of the galvanizing sub-project is, to examine in a quantitative manner the effect of such factors as the physical condition of the surface of the steel, and the crystal structure at the steel surface, on the kinetics of the iron-zinc galvanizing system.

4) Metal Forming

The processes by which cast metal is transformed into plate, sheet, and structural shapes, by rolling, forging and extrusion are, in a metallurgical sense, very complex.

The optimization of production economics and also of resultant material properties can be realized through a thorough understanding of the inter-relationship of such factors as working temperature and temperature range, amount of plastic deformation at each stage and the composition of the alloy being processed. By a good selection of these parameters it is often possible to obtain a significant improvement in properties of the resulting product without resorting to alloying additions.

The immediate objective of the metal forming sub-project is to study in a quantitative way the factors that determine the amount of force required to carry out various types of hot working operations on metals and alloys.

(7) Benefits

It is impossible to arrive at any quantitative or semi-quantitative estimate of the benefit accruing to the Canadian metal working industry as a result of this work.

According to information from the Dominion Bureau of Statistics, the Canadian metallurgical processing industry has an annual production in excess of 1,800 million dollars. This does not include the manufacturing and engineering industry that makes up a significant part of the Canadian metal working industry. It would probably be reasonable to estimate that the total Canadian metal working industry represents an annual production of from 2,000 million to 2,500 million dollars. On a three year basis this is from 6,000 to 7,500 million dollars as compared to the 2.8* million dollars cost of the work described above.

In addition to its research activities, the staff of the Physical Metallurgy Division is required to provide expert advice for policy making and also to act on advisory boards and specification and standards committees in areas concerned with metal processing, fabricating and utilization. The only way in which the necessary expertise can be acquired is through active participation in research and development in these areas.

(8) Projected Costs and Scheduling for Processing of Metals and Alloys Sub-Activity

	Man Years per Year			Cost per Man Years	Total Cost for 3 Years
	72/73	73/74	74/75		
a) New Technology in Melting, Casting and Solidification					
1) Oxygen in Liquid Metals					
Professionals	2	2	2	15,000	90,000
Technicians	3.5	3.5	3.5	8,000	84,000
Overhead					124,200
					298,200
2) Foundry Research					
Professionals	5	5	5	15,000	225,000
Technicians	7.5	7.5	7.5	8,000	170,000
Overhead					282,700
					677,700
3) Melting and Casting of Metals and Alloys					
Professionals	6.5	6.5	6.5	15,000	292,500
Technicians	9.5	9.5	9.5	8,000	228,000
Overhead					347,100
					867,600
			Total		1,843,500

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* This cost figure applies only to the Processing of Metals and Alloys Sub-Activity. The Utilization of Metals and Alloys Sub-Activity costs an additional 3.2 million dollars.

	Man Years per Year 72/73	 73/74	 74/75	Cost per Man Years	Total Cost for 3 Years
b) New Technology in Forming and Fabrication					
1) Powder Metallurgy					
Professionals	3.5	3.5	3.5	15,000	157,500
Technicians	2	2	2	8,000	48,000
Overhead					92,700
					298,200
2) Welding					
Professionals	2.5	2.5	2.5	15,000	112,500
Technicians	2	2	2	8,000	48,000
Overhead					83,400
					243,900
3) Galvanizing					
Professionals	2	2	2	15,000	90,000
Technicians	2	2	2	8,000	48,000
Overhead					78,900
					216,900
4) Metal Forming					
Professionals	2	2	2	15,000	90,000
Technicians	2	2	2	8,000	48,000
Overhead					78,900
					216,900
				Total	972,900

SUB-ACTIVITY 2: UTILIZATION OF METALS AND ALLOYS

(1) Situation

In order to ensure that domestic non-renewable material resources are utilized by Canadian industry in the most effective and efficient ways possible, a thorough knowledge of the properties and characteristics of the metals and alloys with which Canadian industry is concerned must be developed. This involves studying the relationship between alloy composition, structure, mechanical properties, and other characteristics as well as the potential effect of environmental extremes (e. g., Arctic cold; saline and fresh water) on the properties.

The work carried out to achieve this objective is therefore designed to meet the future potential needs of the Canadian economy and national defence, particularly with respect to new and improved alloys suitable for our environment with due regard to conservation of our metal resources and the development of a sound industrial base.

Problems encountered in the utilization of metals and alloys can vary depending on application. It may be required to select the most suitable alloy for a specific application by evaluating properties and characteristics such as strength, corrosion resistance, weldability, formability, etc., of a number of candidate alloys. On the other hand, it may be necessary to modify an alloy or group of alloys so that they would be satisfactory for use in some environment such as the Canadian Arctic or severe marine conditions. Similarly, it may be vital to provide alternative choices of material when supply problems arise in strategic alloying elements, or conversely to explore new applications and outlets for metals in over-supply.

(2) Relation to Other Mines Branch Activities

This Sub-Activity represents the final stage of several sub-activities of the Mines Branch that, taken in sequence, deal with Canada's metal resources commencing with the treatment of the ore and ending with metals and alloys of industrial and engineering usefulness that have been derived from these ores.

(3) Alternatives

In order to achieve the objective of this Sub-Activity two types of projects should be undertaken. These are projects of an applied nature and also projects of a fundamental nature.

The applied projects have the immediate objective of applying basic scientific knowledge to the modification of alloy properties and characteristics in order that they be best suited to specific types of applications.

The fundamental projects have the immediate objective of establishing the basic scientific principles involved in the improvement of mechanical properties and other characteristics (both physical and chemical) of metals and alloys.

(4) Criteria

In accordance with the policy of the Mines Branch, work done in the Physical Metallurgy Division should contribute to the Canadian resource industries either by direct technical support of this industry or indirectly by providing such support to the Canadian metal working industry which represents the immediate customer of the Canadian resource industry.

(5) Preferred Course of Action

In order to fulfil the above criteria the division has undertaken projects of an applied nature and has elected, where possible, to concentrate its efforts on work with long-term objectives that could not be justified by private industry because there would be no immediate return or because facilities and personnel are lacking. In selecting these objectives, particular attention is paid to such typically Canadian conditions as for example, our Arctic environment.

(6) Project Titles and Technical Objectives

a) The Evaluation and Improvement of Metals and Alloys

This project has two objectives. These are:

(a) to evaluate the suitability of an alloy or a group of alloys for use in a specific type of application. This may be, for example, in the fabrication of a structure by welding using the highest strength steel compatible with this type of fabrication. In this case weldability and toughness would be the criteria. Another example could be the correct selection of steels and other alloys best suited to use under Arctic conditions since many alloys lose their toughness at very low temperatures.

(b) the modification of existing alloys to improve some characteristic or combination of characteristics, such as, low temperature toughness, strength, weldability and/or corrosion resistance in order to make it possible for Canadian industry to design and construct a better, more reliable, or lighter structure that may be required for some present or future need (e. g., use in the Arctic or in defence applications).

In order to pursue the objectives outlined above, the work in this project has been organized into three sub-projects. These are:

1) Alloys for Use in the Arctic
2) Steels
3) Non-Ferrous Metals and Alloys

1) Alloys for Use in the Arctic

The use of metals in the Arctic is not new. With the low temperature, problems especially of low resistance to impact and poor welding are encountered. These can be minimized but not avoided by using special materials, ceasing operations at the lowest temperatures when possible, and also by the limited extent of Arctic operations.

With increasing Arctic development requiring year-round operations, problems arising from the effect of low temperature exposure on the properties of alloys will become commonplace. Further, as more and more equipment is used it will be preferable to make it from standard materials where possible, to avoid special production with expensive materials specially for Arctic use.

The objective of the sub-project is to study such properties as toughness, weldability and fatigue, that may be affected by low temperatures encountered in the Canadian Arctic:

(a) the preparation of a monograph on the properties of metals and alloys for use in the Arctic;
(b) to determine which existing materials have the most useful properties;
(c) to improve these properties by modification to thermal or mechanical treatment or by changes in chemical composition;
(d) and to develop welding methods suitable for low temperatures.

While steel is the metal in most common use, the investigations will also cover alloys of nickel, titanium, copper, aluminum and magnesium.

2) Steels

Steels are available with properties such as high strength, good ductility, good corrosion resistance, good environmental cracking resistance, or good fatigue resistance. All too often however, service conditions are encountered that require combinations of several or, indeed, most of these properties. Further, unusual or unpredictable service conditions are sometimes encountered that impair, perhaps only one of a metal's properties, with troublesome consequences nevertheless.

The objectives of these sub-projects are to conduct development work on steels that will:

(a) permit the selection of the alloys best suited to a particular design or set of service conditions;
(b) optimize as many as possible of the desirable properties of metals, such as strength, toughness, formability and weldability, by control or modification of the processing, by compositional changes, or both;
(c) develop new or improved thermal and mechanical treatments and welding methods for the processing of specific alloys.

3) Non-Ferrous Metals and Alloys

The problems encountered with non-ferrous metals and alloys are very similar to those described above in the steel sub-project. The objectives of the non-ferrous alloys sub-project is therefore the same as those for steel above, applied to the alloys of aluminum, copper, magnesium, nickel, titanium, and zinc, for example.

b) Investigation and Consultation in Metal Product Utilization

One of the most direct ways in which the expertise and facilities of the Physical Metallurgy Division are made available is by the provision of consultation services to other government departments and Canadian industry on problems such as the selection and application of the most suitable alloys for a specific use.

The staff of this division is being called upon continually to provide advice of this nature. It is because of the reputation acquired through their research and development work that the advice of our staff is in such demand. It is as a result of this experience that they are able to respond effectively to these requests for advice.

This division also undertakes investigations of specific problems associated with component fabrication and failures.

Such investigations may be carried out at the request of other government departments, Canadian industrial groups, or individual Canadian industries.

For example, failures, all of a similar nature, were being encountered in a certain type of gas pipeline. An investigation of this problem was carried out at the request of the National Energy Board. These failures were found to be associated with a welded joint made during the manufacture of the pipe.

The availability of these types of services to the many small Canadian metalworking industries who, collectively, represent an important sector of the Canadian economy but who, individually, cannot support the necessary staff and facilities, is a very real contribution that the Physical Metallurgy Division makes to the Canadian economy.

c) National and International Scientific and Technical Committees

The objective of this project is to represent the Canadian government on both national committees such as the Canadian Standards Association, Canadian Council of the International Institute of Welding, etc., and also on international groups and committees, such as the International Standards

Organization, the Organization for Economic Cooperation and Development, the Technical Cooperation Program, the American Society for Testing Materials, etc.

In all cases the groups to which this division supplies representatives are associated in a direct way with problems of properties and application of metals and alloys and in some instances with the development of specifications for metals and alloys and their processing. These specifications have a very direct bearing on the activities in the Canadian metal working industry.

d) Certification of Non-Destructive Testing Personnel

The objective of this project is to certify, on behalf of the Canadian Government Specifications Board, personnel who are conducting non-destructive testing by radiography, ultrasonic and other techniques used to detect flaws in metallic components. Examinations for certification are conducted in several centres across Canada.

(7) Benefits

See item on Benefits for the Processing of Metals and Alloys Sub-Activity.

(8) Projected Costs and Scheduling for Utilization of Metals and Alloys Sub-Activity

	Man Years per Year			Cost per Man Years	Total Cost for 3 Years
	72/73	73/74	74/75		
a) Evaluation and Improvement of Metals and Alloys					
1) Alloys for Use in the Arctic					
Professionals	5.5	5.5	5.5	15,000	247,500
Technicians	7	7	7	8,000	168,000
Overhead					273,000
					688,500
2) Steels					
Professionals	6.5	6.5	6.5	15,000	292,500
Technicians	7	7	7	8,000	168,000
Overhead					283,500
					744,000

	Man Years per Year			Cost per Man Years	Total Cost for 3 Years
	72/73	73/74	74/75		
3) Non-Ferrous Metals and Alloys					
Professionals	6.5	6.5	6.5	15,000	292,500
Technicians	8.5	8.5	8.5	8,000	204,000
Overhead					328,500
					825,000
b) Investigation and Consultation in Metal Product Utilization					
Professionals	4.5	4.5	4.5	15,000	202,500
Technicians	6	6	6	8,000	144,000
Overhead					232,500
					579,000
c) National and International Scientific and Technical Committees					
Professionals	2	2	2	15,000	90,000
Overhead					21,000
					111,000
d) Certification of Non-Destructive Testing Personnel					
Professionals	1.5	1.5	1.5	15,000	67,500
Technicians	2	3	3	8,000	64,000
Overhead					92,200
					223,700
				Total	3,171,200

D - MINERAL SCIENCES DIVISION

OBJECTIVES

All projects of the Mineral Sciences Division are dedicated to one or more aspects of the objective of ensuring the most effective conversion and use of minerals and metals. This objective has already been described at some length in the preceding position paper. This report attempts to estimate the kind and magnitude of the effort to be put into the various sub-sub-objectives given in the position paper over the next three years and to give some idea of the benefits that may be expected. It must be borne in mind that as knowledge is accumulated, and as demands change, it is inevitable that the approach to problems will also change, with consequent reassessment of costs and re-deployment of staff.

The six sub-sub-objectives given in the position paper referred to above, are:

1.) to improve on methods of minerals and metals recovery;
2.) to ensure the most effective use of scarce mineral and metal resources;
3.) to ensure the most effective conversion of industrial minerals to useful products;
4.) to ensure the efficient processing of metals and alloys;
5.) to ensure the most effective utilization of metal and mineral products;
6.) to ensure a national awareness of trends and changes in the technology and use of minerals and metals.

The contributions of the Mineral Sciences Division are mainly to Sub-sub-objectives 1, 2 and 6. Extensive technical support is given to 3, 4 and 5, which are largely in the domain of other divisions of the Mines Branch.

SUB-SUB-OBJECTIVE 1 - TO IMPROVE ON METHODS OF MINERALS AND METALS RECOVERY

(1) Introduction

The contributions of the Mineral Sciences Division to this sub-sub-objective are concerned with obtaining fundamental information on the characteristics of minerals that influence their behaviour in refining and extraction processes. Efficiency of separation is becoming increasingly important as more complex ores are treated and as the unit values of most ores decrease and production costs mount.

All methods of mineral separation or concentration depend on exploiting physical or chemical differences between minerals. The basis for separation may range from the obvious differences in density to the more subtle characteristics of the electrical double layer which exists between a mineral particle and the liquid in which it is immersed. Separation schemes depend upon the prior recognition and measurement of mineral characteristics, either bulk or surface, and some understanding of the fundamental nature of the minerals. Emphasis has been placed on those minerals of economic importance in the sulphide group since these are the main sources of Canada's output of base metals. To date almost forty papers on the sulphide minerals have been published by the staff of this division.

(2) Planning Assumptions

Many of the methods of minerals recovery have been largely developed by empirical methods and hence may contain many possibilities for improvement. It is assumed that any bulk or surface characteristics of a mineral must ultimately be explainable on the basis of its chemical composition, the arrangement of the atoms within the crystal, the bond strengths, the impurities present and their distribution, the sharing of charges among the atoms and other less obvious considerations. It is necessary to study many of these important factors before there is any possibility of correlating them with measurable properties or of proposing treatments which would bring about beneficial modifications of bulk or surface properties. The problem is vast and requires an interdisciplinary approach. New concepts that have been developed in the fields of solid state physics and inorganic chemistry, along with the development of sophisticated experimental apparatus and computing techniques, provide an opportunity of arriving at a fundamental understanding of the relation of mineral properties to beneficiation procedures and of elucidating hitherto little known properties that might be of importance in mineral technology.

(3) Outline of Work

a) Studies of Mineral Structures

A knowledge of the distribution of metals between different mineral phases and the physical properties of these phases is important in the assessment of ore grade and potential beneficiation procedures. It also has an important bearing on roasting and smelting operations.

Structure studies are carried out with the aid of X-ray diffraction techniques, infrared spectrometry, electrical and magnetic measurements and recoilless gamma-ray spectrometry. With the number of techniques that are now available, the realistic determination of the composition, structure and associations of minerals in complex ore deposits is practical and can be of immense economic value. The vast amount of data required for such studies has only recently come within reach with the advent of the electron probe micro-analyzer, computer controlled X-ray spectrometers, and with the use of computers for data processing.

Our structure studies have shown that even minor deviations from the simple idealized atomic ratios bring about previously unsuspected differences in characteristics which may possibly be exploited in separation processes or in finding new uses for minerals in the manufacture of useful devices. These deviations in stoichiometry are difficult to distinguish by rough-and-ready field tests and, in retrospect, it may be that they have accounted for the anomalous and unexplained behaviour of certain ores in flotation and other operations. This is an important field for investigation and considerable progress has been made in the determination of the structural differences between close members of families of minerals, notably the copper-iron sulphide family where three distinct minerals close to the idealized chalcopyrite composition ($CuFeS_2$) have been identified and studied. The phase relationships and mineralogical associations studies in the neighbourhood of the chalcopyrite composition have been a major contribution to the continuing Sulphide Minerals Program. A somewhat similar situation exists in the neighbourhood of the pyrrhotite composition, but the investigation is not yet in as advanced a stage as the one previously mentioned.

b) Phase Equilibria

The stability relationships of minerals or synthetic equivalents are being studied in terms of composition and temperature in two, three or more component systems. The work is essential to the structure determination programs, but also has important implications in the high temperature processing of ores and in complex mineralogical studies.

c) Semiconductor Properties

An incidental but by no means minor spin-off of the Sulphide Program has been the recognition of certain semi-conductor properties of sulphides which may be controlled by minor variations in the stoichiometric ratios and which may possibly be exploited in the development of separation processes and solid-state devices. The semi-conducting properties are determined by the measurement of electrical conductivity, thermoelectric power and the Hall effect. To date, work in this connection has been concentrated on nickel sulphide.

d) Crystal Growing

Synthetically-grown mineral crystals are often necessary for work in the division. For this purpose an extensive crystal growing facility has been developed in which crystals with closely controlled compositions may be grown by a variety of techniques. Single crystals of about fifty different mineral compositions, including sulphides, arsenides and sulpharsenides associated with specific projects have been produced.

e) Surface Studies

One of the most useful yet complex concentration processes is that of froth flotation which is used to separate and recover fine material particles and which has been empirically developed over the last half century. It is firmly based on the thermodynamics of surfaces, but there is a wide gap between theory and the practical application of flotation reagents. Attempts are being made to bridge this gap through electro-chemical studies by investigating the electrical phenomena at solid-liquid and solid-gas interfaces such as exist in froth flotation cells. To date work has concentrated on the oxides, but work is now underway towards similar measurements on sulphides.

Another approach to the problem of increasing recoveries by froth flotation is that of irradiating minerals with gamma rays and evaluating the effects by flotation yields. A significant enhancement in the recovery of quartz has already been obtained and, from measurements of the consumption of the adsorption reagent, it appears that the surface activity has been increased. This work is to proceed using other minerals in the expectation that differential response to irradiation will make difficult separations easier and more economical. These experiments concerning improvements in the flotation process have inter-divisional interest and participation and staff experienced in the whole gamut of theoretical and practical skills have cooperated.

f) Process Control

At present there is an active and growing demand for the application of analytical methods for on-stream analysis of concentrates so that separation processes may be operated at maximum efficiency. A suitable radioisotope ore-slurry analyzer was designed and constructed which has numerous economic and practical advantages over the older units using X-ray excitation and X-ray spectrometry. A pilot unit has been set up for the determination of iron and silicon in a low-grade iron ore slurry, but the principles involved may be applied to the determination of many other economically important combinations of elements. Attempts are also being made to measure the water content of non-ferromagnetic slurries by the use of nuclear magnetic resonance.

g) Low Pollution Process Studies

Within the Mines Branch the economics of many mineral processing operations must be re-examined in the light of costs involved in preventing environmental pollution, a factor often overlooked in the past. For example, the winning of metals from sulphide ore by roasting has been the most economic for a very long time during which very little expense was involved in dispersing the millions of tons of gaseous sulphur dioxide into the atmosphere. Today, with the current demand for pollution control, other processes may well be more economic. One such method involves the chlorination of the ores with hydrogen chloride to produce hydrogen sulphide which is later converted to elemental sulphur. The Mineral Sciences Division has supported this work by studying the Sulphide/Chloride systems of Fe(II) and Fe(III), Co, and Ni, for the possibility of encountering troublesome low-melting eutectics, mainly by thermoanalytical techniques.

(4) Benefits

Canada is the third largest producer of minerals, being exceeded only by the U. S. A. and the U. S. S. R. Mineral production accounts for 32 per cent of total exports so that the wellbeing of the Canadian economy is very sensitive to the efficiency and size of the mineral industry. About 120, 000 Canadians are directly employed by the mining and mineral industry and many hundreds of thousands are indirectly employed in servicing, supplying, and transporting its people and products. Our metallic and non-metallic mineral production is valued in the neighbourhood of $5 billion annually and there is every reason to believe that the upward trend will continue in the foreseeable future.

The studies previously described are primarily intended to be of help in solving beneficiation problems and to take advantage of new scientific knowledge in the treatment and use of minerals not only for the long term but for day-to-day problems which arise from increasing use of lower grade and refractory ores. It is important to be able to anticipate difficulties which may occur as a result of changes in mineral composition, mineral intergrowths, grain size, friability, etc. , and the effect these have on the loss of valuable minerals. Our studies clearly show that in many cases close chemical control is not sufficient to determine the nature of the changes and that most direct and effective solutions can only be obtained through an intimate knowledge of mineral characteristics.

It would be unwise to claim to give a meaningful cost benefit ratio because the benefits, once attained, continue long into the future, long after the research and development costs have ceased. Further, there is, more often than not, a long time-lag between the R and D and the application of results. However, some idea of the magnitudes involved may be gained by considering only the important and widely-used process of froth flotation in which a 2 per cent decrease in the use of flotation reagents would represent an annual saving of about $1 million.

(5) Projected Costs and Scheduling: Improved Recovery Methods

	Man Years per Year			Cost per	Total Cost
	72/73	73/74	74/75	Man Years	for 3 Years
Professionals	17	15	14	15,000	690,000
Technicians	17	15	14	8,000	368,000
Overhead					360,000
					1,418,000

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SUB-SUB-OBJECTIVE 2 - TO ENSURE THE MOST EFFECTIVE USE OF SCARCE MINERAL AND METAL RESOURCES

(1) Introduction

Mineralogical research is required on low-grade or highly complex deposits, presently of marginal or sub-marginal interest, in order to improve the probability of their development to meet future demands for minerals and metals products.

In these cases it is particularly essential that beneficiation plants operate at maximum efficiency. It is not uncommon that they are designed to handle a particular type of ore which has been characterized on the basis of samples obtained during initial exploration. However, as mining proceeds, significant mineralogical differences in regard to the minerals present, their composition, and associations, occur in the character of the ore brought to the surface which often results in a drop in recoveries in one or more stages of the beneficiation processes. At this point remedial action, based on a knowledge of the minerals involved, has to be taken in order to restore both grade and recovery to meet the strict economic criteria. The Mineral Sciences Division contributes to this Sub-sub-objective to ensure the most effective use of scarce mineral and metal resources by undertaking mineralogical studies, including the characterization of individual minerals. This work, which involves detailed examination of ore minerals and their assemblages, provides essential information in order to achieve maximum recoveries at all stages of processing. It also contributes to a better understanding of the occurrence and mineral associations in order to improve methods of evaluating and mining the deposits. Attention to some of the more uncommon minerals, which may be a source of valuable rare elements, or indeed a source of pollution, is needed. The development of substitutes for some metals, which although common today will inevitably become a critical need for future generations, is also an important objective.

(2) Planning Assumptions

It is assumed that the mining and processing of ores will continue to be a major activity in Canada's economy. It is evident that the trend is towards the mining of lower grade and more complex ores and that certain districts, where deposits are currently sub-marginal because of grade or complexity, will become important sources in the future as economic and technological changes take place.

Ore deposits within districts exhibit certain characteristics and relationships that are of importance in the processing of the ore in the extraction process. Each district has its own distinctive ore mineralization, although there may be some systematic change in the distribution of values throughout the district, as mineral zoning is more often than not a characteristic unique to each district. There are a great many permutations and combinations of compositional variations, zoning, textural relationships, and significant alterations that are essential to consider at all stages in the mining and processing of the ores. It is in this context that regional mineralogical studies are carried out. One of the principle advantages of such an approach is to integrate information obtained from studies of individual deposits in a district so that the sum total will provide information on trends that can be projected from one deposit to another.

(3) Outline of Work

a) Mineralogical Research on Low-Grade or Highly Complex Deposits on a Regional Basis

Priority of attention is given to regions whose deposits have presented particular problems. The division sends mineralogists into the field and, in cooperation with the mining companies, collects samples from drill cores, working faces and mills for study in the laboratory.

The studies of the minerals present sometimes reveal new or rare mineral species which, quite aside from their own economic interest, may very well complicate standard recovery procedures. In this case the mineral is subjected to physical, chemical, and structural analyses.

1) Cobalt-Gowganda Districts of Ontario

Work has now been completed on a very detailed study of the silver deposits of the Cobalt and Gowganda districts where operators have had many difficulties owing to the small size of the orebodies and the great mineralogical complexity of the ore. This work was undertaken at the specific request of the mine operators.

2) Highland Valley District of British Columbia

A detailed study of the Highland Valley porphyry copper-molybdenum deposits of British Columbia has recently been undertaken in both the laboratory and in the field. Several mines in the district are in various stages of planning some of the largest operations in the country. It is particularly important that their work be supplemented by our own detailed mineralogical studies so that relevant information may be made available in time to be of use in the design of the mills. These studies make possible a comparison with related deposits occurring in the western regions of North and South America and it is hoped that they will optimize recoveries from ores of this region.

3) Red Lake District of Ontario

Ores from the first producing base-metal mining operations in this area are being investigated along with six other prospects in order to characterize the mineral constituents, mineral compositions, distributions and mineral associations of the district. A comprehensive preliminary report on these investigations is now being prepared.

4) Mount Pleasant District of New Brunswick

These deposits, in the vicinity of Mount Pleasant in southwest New Brunswick, are believed to contain some hundreds of millions of tons of material. Although they contain important quantities of copper and zinc, their major interest is related to the presence of molybdenum, tungsten, indium and tin, all of which are of economic importance to Canada. The difficulty with these deposits lies in the complexity of the mineralogical assemblages and the extremely fine grain size of the mineral components. From polished sections many minerals have been identified and their intergrowths studied. From this information methods of separation are chosen for investigation.

b) Mineralogical Research on Low-Grade Deposits on an Elemental Basis

1) Nickel

Because of the great importance of nickel--in terms of both commercial and strategic interest--it was decided to investigate the large resources of low-grade nickel-bearing intrusions that occur in Canada. The distribution of nickel among the various mineral phases is being determined in order to provide basic information in the evaluation and beneficiation of these materials which occur in such vast quantities that successful recovery would represent a tremendous increase in our national nickel reserves. To date, work has concentrated on asbestos-bearing serpentines from Quebec, Ontario, Manitoba, and British Columbia.

c) Mineralogical Support

Mineralogical investigations of various ores and mill products are undertaken at the request of other divisions of the Mines Branch and industrial organizations. These investigations include identification of the minerals, the evaluation of characteristics likely to affect beneficiation of the ores and much interpretative work. This work is usually done by the use of optical microscopy, X-ray diffraction and electron-probe microanalysis. Extensive use is also made of differential thermal analysis (DTA) and the thermogravimetric analysis (TGA) when information is required on the thermal effects occurring when minerals are heated to high temperatures. This latter information is useful in smelting and roasting operations in that the temperature, rate and extent of reactions can be followed quantitatively, and useful thermodynamic data can be obtained. The surface areas of aggregates of mineral particles are determined by gas absorption techniques in connection with the consumption of flotation reagents, rates of oxidation or other reactions, or in the use of certain minerals as adsorbers in environmental work.

d) Analytical Research and Support

The effectiveness of the analytical support given to projects throughout the Mines Branch is highly dependent on a strong research effort in the division. Research is usually initiated either as a result of some particular problem encountered in the support effort or because of some need, foreseen by the staff or by committees on which staff members sit, or both. For example, the combustion determination of sulphur was undertaken both to improve precision when using very small amounts of material and to contribute to the Standards Program. At the present time a staff member is spending full time writing up methods that have been developed or adopted for use in these laboratories. Since many of the problems are common throughout the mineral and metallurgical industry in Canada, this manual is to be made available to laboratories throughout Canada. The Analytical Chemistry Section has developed improved methods of analysis for determination of the rare-earth and platinum group elements and is at present working on methods for the determination of manganese, titanium, silicon, aluminum, calcium and magnesium in iron ores by optical methods.

Analysis of a support nature include the whole range of ferrous and non-ferrous alloys, analyses for mineralogical studies, mill products, slags, wood ash, standard materials, ores, minerals and gangue. Much of this work is done in the Chemical Section by a variety of chemical and physical techniques. The Spectrochemistry Section conducts analyses, using X-ray fluorescence and emission spectroscopy on a wide range of materials, and neutron activation analysis mainly for oxygen and fluorine. The X-ray Diffraction Group supplies identification of powdered samples which usually consist of a mixture of minerals and can usually detect these above the 5-10 per cent level.

(4) Summary of Support Services (1/10/70 - 31/3/71)

Laboratory	Services Rendered to: Mines Branch	Other Government Agencies	Industry and Universities	Standards Projects	Total Determinations
	%	%	%	%	
Analytical Chemistry	90.5	4.0	3.2	2.3	6,689
Spectrographic	25.1	0.4	0.5	74.0	37,927
Electron Probe	93.8	4.7	1.5	--	1,514
Neutron Activation	88.0	--	12.0	--	102
Magnetic	84.4	--	15.6	--	64
X-ray Fluorescence	100	--	--	--	142

(5) Projected Costs and Scheduling: Ensuring Effective Use of Resources

	Man Years per Year 72/73	73/74	74/75	Cost per Man Years	Total Cost for 3 Years
Professionals	11	13	14	15,000	570,000
Technicians	16	18	19	8,000	424,000
Overhead					225,000
					1,219,000

(6) Benefits

Minerals underground are only of value insofar as they may be recovered economically. As we gain engineering and scientific efficiency in mining and treating ores, we greatly augment our useful mineral resources and thus help meet the steadily increasing demands of an expanding world population. As Canada's high-grade and favourably located orebodies are gradually being used up, the problem of making large low-grade mineral deposits into valuable ore deposits must be faced. This is being met, in part, by increasing the scale of operations, as is evident in the present mining activities in the Highland Valley of British Columbia. A complementary approach pursued in the Mineral Sciences Division is that of detailed mineralogical study of the ores in districts having low-grade or complex ores in the knowledge that each district has its own distinctive ore mineralization and that the data gained can be judiciously applied to all operations in that district. With such vast tonnages involved, it can be seen that even a slight increase in the efficiency of separation processes becomes economically important.

The evaluation of these activities is difficult in view of the many possibilities of new discoveries and changing needs, but it is evident that such work is necessary if we are to maintain the health of the mining industry for many years into the future.

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SUB-SUB-OBJECTIVE 3 - TO ENSURE THE MOST EFFECTIVE CONVERSION OF INDUSTRIAL MINERALS TO USEFUL PRODUCTS

SUB-SUB-OBJECTIVE 4 - TO ENSURE THE EFFICIENT PROCESSING OF METALS AND ALLOYS

SUB-SUB-OBJECTIVE 5 - TO ENSURE THE MOST EFFECTIVE UTILIZATION OF METAL AND MINERAL PRODUCTS

(1) Introduction

The contributions of the Mineral Sciences Division to these three sub-sub-objectives are mainly concerned with scientific and technical support for programs originating in other divisions of the Mines Branch involved with these objectives. The predominant support is in the form of elemental analysis of metals and alloys and elemental and mineralogical analyses of minerals and ores and mill products after various stages of processing. This is accomplished by chemical, physical and mineralogical techniques.

On a smaller scale, but nevertheless of great importance, are projects of inter-divisional interest such as the surface properties of mineral particles, which are of predominant importance in the flotation process for metallic and non-metallic minerals, and the thermodynamic properties, which are fundamental to roasting and smelting processing and in the development of alternate processes to these, in view of current concern for reducing atmosphere pollution. The division also undertakes extensive surveys of the literature on subjects which may also be of interest to other divisions, e.g., the production and/or the elimination of sulphur dioxide from the atmosphere.

(2) Planning Assumptions

It is assumed that the requests for analytical services will continue or perhaps increase during the foreseeable future and that the demands for precision and for the analyses of more elements will certainly increase in view of the concern for the release of toxic elements into the environment. The standardization of analytical methods will continue and the use of standard reference materials will increase.

(3) Projected Costs and Scheduling: Ensuring Effective Conversion of Minerals, Processing of Metals and Utilization of Metals and Minerals

	Man Years per Year			Cost per Man Years	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	3	3	3	15,000	135,000
Technicians	3	3	3	8,000	72,000
Overhead					48,000
					255,000

SUB-SUB-OBJECTIVE 6 - TO ENSURE A NATIONAL AWARENESS OF TRENDS AND CHANGES IN THE TECHNOLOGY AND USE OF MINERALS AND METALS

(1) Introduction

Perhaps the most obvious and topical trend in all branches of the mineral industry today is the diminution or the elimination of environmental pollution. Thus, another important factor has been added to the overall economics of many mining processes and this division must therefore be in a position to supply newly-needed information on the characteristics of minerals which are of significance in alternative processes.

The last two decades have seen the products of organic chemistry, chiefly in the form of artificial fibres, plastics and resins, steadily gain ground in competition with mineral and metal products in building construction, transportation, plumbing and home appliances. This may ultimately be very desirable, for these materials are derived from replaceable resources, but every effort should be made to achieve efficient and effective use of Canadian minerals in the interests of both conservation and orderly economic development.

Within the field of metal and mineral products, the substitution of one material for another, in a specific application, is of continuing importance and, for this reason alone, the relative importance of certain ores varies from time to time. There is a necessity to observe and be aware of these trends and to be in a position to supply data on minerals of coming importance well in advance of the demand.

Applications of solid state theory, in particular during the last decade, have created a demand for elements of hitherto little value. For example, phosphors for colour television tubes have created a demand for particular rare earth minerals. A new technology depending upon the use of amorphous materials (which includes glasses) for producing simple and inexpensive switching devices for computers is now being opened up. This may make certain minerals suddenly important and it is a necessity to be cognizant of these latest developments.

(2) Planning Assumptions

It is assumed that the mineral industry will remain an important segment of the economy for decades to come but that foreign competition will become more severe as mineral discoveries are made in developing countries and as most countries become more industralized. It is also assumed that the mining and milling of low-grade and complex ores will greatly increase, that many new processes will be developed and that the growing concern with pollution will greatly affect the economics of many mining and milling processes.

In the mineral industry the trend towards standardization of chemical analyses and other methods of characterizing minerals is assumed so that our products may be adequately described and their quality controlled. The adage "Everyone should know what he is selling" is as true today as when it was written.

It is recognized that trends and breakthroughs in technology will occur and that awareness and ability to cope with them depends on maintaining a competent staff equipped with the best research facilities available in the interdisciplinary field of mineral sciences. This sub-sub-objective may only be achieved by having a capability to carry on both practical and fundamental work so that new concepts, which tend to be increasingly more complex, can be appreciated and developed in the required directions.

(3) Outline of Work

a) Metallurgical Processes Having an Environmental Aspect

This subject has been dealt with in some detail in a recent contribution to a report on environmental improvement activities in the Mines Branch.

b) Standards

Standards, in terms of both standard reference materials and standard methods of analyses, are in demand by industry and government in order to provide a basis for the sale and use of minerals, metals and ores.

1) Standardization of Chemical Analysis

The division promotes this objective nationally--sometimes through the Canadian Standards Association--by developing methods of chemical analyses where the need is evident to solve a Canadian problem. On the international scene, the division participates by development, evaluation and recommendation of methods of chemical analyses in the work of several analytical committees of the International Standards Organization where problems of a more general nature are dealt with. It likewise participates in the work of the American Society for Testing and Materials, the U. S. Bureau of Standards, and the OECD.

2) Standard Materials

In addition to the work on analytical methods, the division is instrumental in the production of standards for the platinum group metals, standard reference ores containing metallic minerals, and ferrous and non-ferrous spectrographic standards.

c) New or Extended Fields of Application

1) Semiconducting Applications

Research in this division has shown that minor variations in the metal-sulphur ratio or changes in the temperature can determine whether or not some sulphide minerals are semi-conducting. In an age wherein electronics are becoming broadly based on solid state devices, these findings have technological and economic significance beyond the mineral industry, and could possibly result in the substitution of sulphides for the more expensive silicon and germanium in some semi-conductor devices used today. Certain optical properties of numerous silicate minerals have been found to be due to electron-exchange processes between transition metal ions in different states of oxidation. When the concentration of the interacting ions is sufficiently high, the materials may act as semi-conductors and polarizers of light. Both these effects have potential applications in the near future.

2) Catalytic Applications

The application of platinum metals as catalysts in automobile exhaust systems is expected to rise sharply as efforts are increased to reduce pollution of the atmosphere. The division has developed unique capabilities in the analytical chemistry of the platinum group metals which should materially assist the anticipated greater demand for them.

3) Application of Magnetic Materials

Canada has an abundance of raw materials suitable for the production of ferrites, a relatively new class of magnetic materials with non-metallic compositions. It is a field in which Canada can hope to reap a rich benefit if it is in a technologically competent position. The several companies manufacturing ferrites on a small scale have very little research support and it is for this reason that the division has developed a unique capability for the production and evaluation of ferrites. One forecast indicates a North America requirement of over one million pounds in 1973. If half the strontium carbonate required for ferrites could be supplied by Canadian mines, it would represent a value of the order of ten million dollars per year to the mining industry.

d) Characterization of Minerals of Imminent Interest

Processing methods are developed for the efficient separation and extraction of products currently in demand, the complete composition of the tailings usually being of little concern. As new uses for relatively scarce elements are being found or as some are recognized as being toxic to the environment when leached by weathering, their extraction becomes of concern. Separation processes must therefore be re-examined in view of the changed conditions. It is thus important that the division be aware of technological and environmental demands and that the minerals containing the elements concerned be characterized in view of the probable development of modified separation and extraction processes.

(4) Benefits

The benefits of ensuring a national awareness of trends and changes in the technology and use of minerals and metals may be subdivided into those derived from increased exports, in terms of increased incomes, and those derived from the availability of materials in sufficient quantities to meet the present and long-term needs of our society. It is perhaps easier to try to visualize the consequences of falling behind in these important factors. For example, if Canada—even for a limited time—should be unable to supply common raw or processed materials to close specifications, we would probably lose the market to competitors. Once lost, the market would be much more difficult to regain, so that even though we subsequently greatly improved our product our export customers might be lost forever. Our Canadian manufacturers must be assured that our mineral products are second to none in quality and consistency, otherwise they will be forced to import raw materials for their purposes. In the case of universally rare minerals and metals, the problem is one of being able to develop new and more efficient extraction processes and to supply many of them in very high purity. When new uses for a product of our mines becomes known, Canadian scientists must be aware of this and be able to advise potential customers of details of their uses; otherwise others will.

These benefits cannot be given a price tag, but it is evident that adaptability to changing conditions is a necessity in an economic society.

(5) Projected Costs and Scheduling: Ensuring National Awareness of Changes in Technology and Uses of Minerals and Metals

	Man Years per Year			Cost per Man Years	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	7	7	7	15,000	315,000
Technicians	5	5	5	8,000	120,000
Overhead					142,500
					577,500

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E - MINERALS AND METALS TECHNOLOGY ACTIVITY: 3-YEAR FORECAST

SUB-ACTIVITY AND SUB-SUB-ACTIVITY	PTO	Man Years			Cost/ Man Year	Total 3 Years
		72/73	73/74	74/75		
A. Mineral Processing Division						
Improvement in Mineral and Metal Extraction Methods						
Beneficiation Techniques	P	2	2	2	18,000	108,000
	T	2.5	2.5	2.5	8,000	60,000
	O					30,000
						198,000
Optimal Processing of Metallic Ores	P	2	2	2	19,000	114,000
	T	3	3	3	8,000	72,000
	O					45,000
						231,000
Fine Materials Handling	P	1	2	2	16,000	80,000
	T	1.5	2.5	2.5	8,000	60,000
	O					15,000
						155,000
Utilization of Metallic Mineral Resources						
Increasing Recovery	P	2	2	2	18,000	108,000
	T	4	4	4	8,000	96,000
	O					90,000
						294,000
Research on Complex Ores	P	3	3	3	18,000	162,000
	T	5.5	5.5	5.5	8,000	132,000
	O					90,000
						384,000
Recovery from Wastes	P	3	3	3		156,000
	T	3	3	3		78,000
	O					91,500
						425,500
Determining Changes in Minerals Technology and Utilization	P	2	2	2	18,000	108,000
	T	0.5	0.5	0.5	8,000	12,000
	O					30,000
						150,000
Conversion of Industrial Minerals						
Processing Techniques	P	2.5	2.5	3.5	18,000	153,000
	T	2	3	3	8,500	68,000
	O					70,000
						291,000

P = Professional T = Technician O = Overhead including equipment and supplies

SUB-ACTIVITY AND SUB-SUB-ACTIVITY	PTO	Man Years			Cost/ Man Year	Total 3 Years
		72/73	73/74	74/75		
Beneficiation of Canadian Industrial Minerals	P	1.5	1.5	1.5	18,000	81,000
	T	4	4	4	8,250	99,000
	O					70,000
						250,000
Improved Processing of Ceramic Raw Materials	P	2.5	2.5	2.5	18,000	135,000
	T	2	2	2	9,500	57,000
	O					90,000
						282,000
Aggregates for Construction	P	1.5	1.5	1.5	16,000	72,000
	T	1	1	1	8,000	24,000
	O					46,500
						142,500
New Methods of Forming and Firing	P	1	1	1	19,000	57,000
	T	1	1	1	9,000	27,000
	O					40,500
						124,500
Morphology of Particulates	P	0.5	0.5	1	16,000	32,000
	T	1	1	1	9,000	27,000
	O					21,000
						80,000
Utilization of Industrial Minerals						
Quality of Construction Materials	P	4	4	4	18,000	216,000
	T	3	3	3	9,000	81,000
	O					92,000
						389,000
Properties and Uses of Rocks, Minerals and Ceramics	P	6	6	7	18,000	342,000
	T	2.5	3.5	4.5	8,500	89,250
	O					173,000
						604,250
Evaluation of Industrial Mineral Deposits and Products	P	1.5	1.5	1.5	16,000	72,000
	T	0.5	0.5	0.5	8,000	12,000
	O					41,000
						125,000
Sub-total: Mineral Processing		73.0	77.0	80.5		4,125,750

SUB-ACTIVITY AND SUB-SUB-ACTIVITY	PTO	Man Years			Cost/ Man Year	Total 3 Years
		72/73	73/74	74/75		
B. Extraction Metallurgy Division						
Minerals and Metals Extraction						
Hydrometallurgical Treatment of Common Base Metal Sulphide Ores	P	5.25	5.25	5.25	15,000	236,250
	T	3.4	3.4	3.4	8,000	81,600
	O					194,150
						512,000
Hydrometallurgical Treatment of Less Common and Precious Metals	P	2.25	2.25	2.25	15,000	101,250
	T	1.35	1.35	1.35	8,000	32,400
	O					82,350
						216,000
Control, Mathematical Modelling and Optimization Techniques	P	3.2	3.2	3.2	15,000	144,000
	T	1.0	1.0	1.0	8,000	24,000
	O					99,000
						267,000
Methods to Reduce Corrosion Costs	P	3.0	3.0	3.0	15,000	135,000
	T	1.2	1.2	1.2	8,000	28,800
	O					85,200
						249,000
Analytical, Mineralogical and Mathematical Support Services	P	4.4	4.4	4.4	15,000	198,000
	T	7.5	7.5	7.5	8,000	180,000
	O					141,000
						519,000
Effective Use of Scarce Resources						
Electroplating Development	P	1.9	1.9	1.9	15,000	85,500
	T	2.1	2.1	2.1	8,000	49,600
	O					61,900
						207,000
Ensuring an Awareness of Trends and Changes in Technology						
Information, Consultation and Advice	P	3.75	3.75	3.75	15,000	168,750
	T	--	--	--	8,000	--
	O					128,250
						297,000
Sub-total: Extraction Metallurgy		40.3	40.3	40.3		2,267,000

SUB-ACTIVITY AND SUB-SUB-ACTIVITY	PTO	Man Years			Cost/ Man Year	Total 3 Years
		72/73	73/74	74/75		
C. Physical Metallurgy Division						
Processing of Metals and Alloys						
Oxygen in Liquid Metals	P	2	2	2	15,000	90,000
	T	3.5	3.5	3.5	8,000	84,000
	O					124,200
						298,200
Foundry Research	P	5	5	5	15,000	225,000
	T	7.5	7.5	7.5	8,000	170,000
	O					282,700
						677,700
Melting and Casting of Metals and Alloys	P	6.5	6.5	6.5	15,000	292,500
	T	9.5	9.5	9.5	8,000	228,000
	O					347,100
						867,600
Powder Metallurgy	P	3.5	3.5	3.5	15,000	157,500
	T	2	2	2	8,000	48,000
	O					92,700
						298,200
Welding	P	2.5	2.5	2.5	15,000	112,500
	T	2	2	2	8,000	48,000
	O					83,400
						243,900
Galvanizing	P	2	2	2	15,000	90,000
	T	2	2	2	8,000	48,000
	O					78,900
						216,900
Metal Forming	P	2	2	2	15,000	90,000
	T	2	2	2	8,000	48,000
	O					78,900
						216,900
Utilization of Metals and Alloys						
Alloys for Use in the Arctic	P	5.5	5.5	5.5	15,000	247,500
	T	7	7	7	8,000	168,000
	O					273,000
						688,500
Steels	P	6.5	6.5	6.5	15,000	292,500
	T	7	7	7	8,000	168,000
	O					283,500
						744,000

SUB-ACTIVITY AND SUB-SUB-ACTIVITY	PTO	Man Years			Cost/ Man Year	Total 3 Years
		72/73	73/74	74/75		
Non-Ferrous Metals and Alloys	P	6. 5	6. 5	6. 5	15, 000	292, 500
	T	8. 5	8. 5	8. 5	8, 000	204, 000
	O					328, 500
						825, 000
Investigation and Consultation	P	4. 5	4. 5	4. 5	15, 000	202, 500
	T	6	6	6	8, 000	144, 000
	O					232, 500
						579, 000
National and International Scientific and Technical Committees	P	2	2	2	15, 000	90, 000
	O					21, 000
						111, 000
Certification of Non-Destructive Testing Personnel	P	1. 5	1. 5	1. 5	15, 000	67, 500
	T	2	3	3	8, 000	64, 000
	O					92, 200
						223, 700
Sub-total: Physical Metallurgy		109. 0	110. 0	110. 0		5, 990, 600
D. Mineral Sciences Division						
Improving Recovery Methods for Minerals and Metals	P	17	15	14	15, 000	690, 000
	T	17	15	14	8, 000	368, 000
	O					360, 000
						1, 418, 000
Ensuring Most Effective Use of Scarce Mineral and Metal Resources	P	11	13	14	15, 000	570, 000
	T	16	18	19	8, 000	424, 000
	O					225, 000
						1, 219, 000
Ensuring Effective Conversion of Minerals, Processing of Metals, and Utilization of Metals and Minerals	P	3	3	3	15, 000	135, 000
	T	3	3	3	8, 000	72, 000
	O					48, 000
						255, 000
Ensuring National Awareness of Changes in Technology and Uses of Minerals and Metals	P	7	7	7	15, 000	315, 000
	T	5	5	5	8, 000	120, 000
	O					142, 500
						577, 500
Sub-total: Mineral Sciences		79	79	79		3, 469, 500
TOTAL - MINERALS AND METALS		301. 3	306. 3	309. 8		30, 199, 950

3. ENERGY ACTIVITY

OBJECTIVE

To promote the fullest and best use of Canada's energy resources within the framework of a strong domestic industry and of a clean environment.

BACKGROUND AND SCOPE

Canada's energy resources are plentiful, but except for nuclear energy are subject to relatively high transportation or transmission costs because of their remoteness from major industrial centres. The national dependence on fossil fuels is growing—with a conservative estimate of requirement attaining about three times the present level by the end of the century.

The Energy activity is dedicated to:

(1) Maintaining a national inventory of the quality of fossil fuel resources.
(2) Beneficiating the more plentiful low-grade petroleum, coal and uranium resources.
(3) Producing a material suitable for use in metallurgy and thermal power generation from coal whose physical state has been altered in order to transport it by pipeline or by other solids handling techniques.
(4) Converting coal most effectively to high-carbon products such as coke and char for metallurgical uses.
(5) Studying metallurgical methods for producing primary metals with minimal use of energy.

The location and magnitude of Canada's fossil fuel resources are delineated by the Geological Survey of Canada. The function of the Mines Branch is to assess the quality of these resources in terms of the current state of the industry, and to provide the essential data for the development of new processing techniques. The evaluation of the quality of resources, in terms of potentially different types of utilization, is well illustrated by considering coal. This raw material may be evaluated from the point of view of thermal-power production, the manufacture of metallurgical coke, gasification to methane, synthetic liquid-fuel production, and the production of activated char for pollution control.

In a similar manner, it is essential to evaluate the quality of Canada's petroleum and natural gas resources to determine the type of future refining capacity that will be needed, and the extent of the contamination of the crude oils with sulphur.

The evaluation of Canada's fossil fuels has been a function of growing importance since the inception of the Fuels Division in 1912. The information obtained is essential in almost every aspect of utilization, and provides a basis for future planning. Contributions to this program are made by the Petroleum and Gas Analysis Laboratory, the Solid Fuels Laboratory, and the Petrographic Laboratory.

Peat, which is a commodity of growing importance in agriculture and the centre of a growing industry, is given assistance by providing the industry with advice on production methods, methods of quality control and the quality of various areas within a bog.

Oil

The high degree of foreign ownership and control in the oil industry (practically 100%) raises the important question as to whether Canada is maximizing its benefits from the development of this resource inasmuch as most corporate decisions are made outside of the country. Very little process research is done by Canadian subsidiaries of these oil companies and no other government agency is doing, or has the facilities for doing, process research on Canadian crude resources. It would seem short-sighted for the government, through the Mines Branch, not to continue at an increased rate to work toward supplying techniques that would increase the return to Canada from oil operations in terms of conversion efficiency, resource conservation and a cleaner environment.

The Fuels Research Centre's petroleum refining research activity was conceived at the end of World War II because it was realized that Canada's potential in low-grade petroleum is substantial, notably in the "oil sands" deposits with which the Department has had a long association. These fossil fuel reserves contain large amounts of pollutants, sulphur, nitrogen, metals and fine mineral matter. Air pollution regulations have a profound effect on the use of these heavy oil resources. In addition, large reserves are presently of border-line quality and will quickly lose value as air pollution regulations become more stringent. The development of practical and economical means of reducing the impurities and of generally improving the quality and value of these oils is essential to maintain a steady supply of Canadian heavy fuels for domestic use and export.

Coal

The coal area of this activity provides a good example of a knowledge base possessed by the Department being put to good use when the fortunes of an energy mineral change from near extinction to a strong upsurge in demand. It has been unequivocally established that if adequate knowledge in this gap area (due in part to the size and fragmented nature of the Canadian coal industry) were not available at the present time for the development of coking coal deposits in Western Canada, there would have been difficulty in negotiating contracts with Japan. Since the Western coking coals are not similar to the classical coking coals of the United States and Europe, precise expertise on coking quality was not available. The reason for so many of the demands on the Department by the industry is that the industry itself discovered these deficiences in knowledge.

A similar situation arose in connection with the proposal for moving coal by pipeline to Roberts Bank and possibly also to Ontario. The pipeline developer, ShelPac, asserted they could find no source of knowledge on the treatment of coking coal after being transported by pipeline and therefore requested the Department to solve a number of technological problems in this area.

A corollary to the foregoing is the realization some years ago by the Canadian steel industry that the Department possessed the only facilities available in Canada that would enable the steel companies to enter the era of increased blast furnace throughput by using enriched iron ore feeds requiring carefully prepared blends of low-ash coking coals. In addition, it was realized that no systematic carbonization research was conducted outside this Department, studies being conducted only on an individual company basis. Hence, in 1965 the Canadian Carbonization Research Association was founded because of the progressive character of the Canadian ferrous industry and because of the Branch's traditional policy of assisting industry develop its own R & D centres. The Association contributes 20 per cent of the cost of the cooperative research program ($250,000 per year) and through its board of directors guides the research on CCRA programs carried out at the Branch.

The coal research activity is expected to continue in its present state to 1980-85 at which time most of our reasonably accessible coal reserves should be outlined and deployed. Hopefully, a Canadian industrial coal research institute may be formed, possibly based on the existing association.

The scope of the coal portion of the Energy Activity includes the following: evaluation of coals available now and in the future from both Canada and the U.S. (as used by the Ontario steel industry) for both export and domestic use, new methods of upgrading fine coal to produce low-ash and low-sulphur coals (this latter objective is of particular importance to the Cape Breton coal industry), new methods of dewatering coal using oil-assisted drying methods (to obviate the need for expensive, hazardous and damaging thermal drying techniques), and improvement to the coking process itself. These latter studies revolve around economical and safe means of improving output by preheating the coal charge, by agglomerating the charge and by using additives such as coke breeze to displace more costly low volatile coals. Entirely new methods of coking are also being investigated, particularly the type of process known as "form-coking", which embraces special coal up-grading and agglomeration methods as well as the novel coking step itself.

Since the delivery cost of coal is normally equal or greater than the cost at the mine-head, it can be seen that transportation plays a continuing important role in the industry. The Energy Activity deals with several aspects of bulk solids transportation. Of particular importance is the study of the hydraulic transport by slurry pipeline of coal to be used for coking where a solution to the problem of dewatering and size adjustment to the levels required for the coke oven is in process of development. Attention is also being paid to the problems of the transport of coke where its low bulk density is a major disadvantage. The application of carbonization techniques to the treatment of low-rank coals to allow their economic transport for use as a reductant in some direct reduction iron processes, and even for combustion purposes, is being investigated.

Metals Reduction

Metallurgical opinion indicates that although the iron blast furnace will remain for many years a principal producer of pig iron, less capital intensive equipment aimed at attaining eventually a continuous process from ore to steel will evolve. Several reduction methods have been conceived and patented, but the needed research has been restricted because of the urgency of the coal program. However, some progress is being made with the pilot scale Shaft and Electric furnace combination that has reduction in energy consumption as one of its principal objectives. At present the emphasis is on pollution abatement in smelting operations, particularly in ferroalloys. Pyrometallurgical and metal refining operations use by far the largest segment of industrial energy and therefore afford the maximum possibility for reducing the amount of energy in the various processes. This is an important objective of the Energy Activity and is one of the main reasons for combining primary metals with energy (with emphasis on solid fuels) in one centre. The cost of the Energy Activity (conducted in the Fuels Research Centre, Metals Reduction and Energy Centre, Extraction Metallurgy Division and Physical Metallurgy Division of the Mines Branch) is estimated for 1972/73 at $1,539,000 with a manpower use of 87 man-years.

Special Research

The objective of this sub-activity is to investigate by literature surveys, critical analyses of reports, attendance at technical or scientific meetings, laboratory experiments and studies:

1) Research in the processing and utilization of coal fines available in Canada for production of coke.
2) Research in the utilization of Canadian coals, cokes and associated products in treatment of Canadian ores and metallurgical products.

3) Research on special control analytical methods:

   (a) To investigate and develop simple and cheap analytical methods particularly suitable for small coal plants and for field application.
   (b) To provide control analytical procedures for programs within the Mines Branch.
   (c) To develop laboratory apparatus for evaluation, characterization and exploration of conventional and novel processes involving coal, coke and associated materials and minerals.
   (d) To investigate processes for reduction of pollution to soil, stream and atmosphere by products of the coal and coke industry.

4) Research on various economic and scientific aspects of the utilization of fuels (mainly coal) as sources of energy or as reducing agents in metallurgy.
5) Planning, programming and administration of the Metals Reduction and Energy Centre.

Because of the very long distances between Canadian fuel resources production and consumption areas, their efficient utilization, including processing (such as preparation, carbonization or coking), transportation and storage, is very important and it is desirable to research any possibilities of reducing the costs or improving the efficiencies of processing, transportation and storage, on both existing and potential operations.

Radioactive Minerals

The Mines Branch aims to ensure the efficient use of low-grade radioactive mineral resources:

a) by developing new technology for extracting uranium, thorium and other values which might be present from low-grade, Canadian radioactive ores;
b) by developing new methods for the chemical analysis of radioactive ores, metallurgical products and high-grade uranium precipitates;
c) by acting as official umpire in cases where the analysis of high-grade precipitate done by the buyer and seller do not agree.

With the developing need for expanded Canadian production of uranium beginning in the late nineteen forties, the Mines Branch was charged with the responsibility of developing processes that could be used to recover uranium from the low-grade deposits then being discovered. A special division of the Branch was set up to deal with the problems and the efforts of this group were remarkably effective. The main features of all of the processes now used in the treatment of Canadian uranium ores were worked out by the group. Pilot plants, designed, constructed and operated under the direction of the Mines Branch staff, developed the engineering data needed for full scale plant design and provided the means for training industrial personnel in the new technology being developed.

Since then, the Mines Branch has continued to conduct development studies aimed at improving the processes as they were originally conceived. Now the Mines Branch projects carry the studies to the point where feasibility has been demonstrated on a bench scale. Usually additional studies have been done in cooperation with industry on a pilot plant or plant scale at the operating sites.

A - FUELS RESEARCH CENTRE

SUB-ACTIVITY 1: NEW TECHNOLOGY IN BENEFICIATION OF LOW-GRADE PETROLEUM RESOURCES

Objective

"To ensure the use of large petroleum resources of low-grade".

Sub-Sub-Activity 1: Hydrocarbon Processing and Catalysis Research

Objective

"To develop processes, process equipment and catalysts for upgrading low-grade petroleum resources to permit their orderly and balanced utilization within a clean environment".

(1) Situation

In the early 1950's, an integrated program was begun at the Fuels Research Centre which included studies on the chemical structure of McMurray bitumen and other complex hydrocarbons and research on catalysts essential for refining and pioneering engineering research for converting these impure, viscous bitumens and other impure crude oils and residues to marketable petroleum products. Conversion was based on the use of hydrogen under high pressure to saturate the hydrogen-deficient fuels and to remove impurities, particularly sulphur, thus avoiding environmental pollution. This small-scale but technically comprehensive federal effort in petroleum refining research provided a precise knowledge base for the government and stimulation to the largely non-Canadian oil industry to practise conservation-oriented refining methods.

This type of integrated program is costly both in equipment, much of which is custom-built, and in extensive training of staff. The Corkstown Complex was conceived in 1958 largely because of the petroleum research activity and hence its functional buildings are separated for maximum safety.

(2) Planning Assumptions

Air pollution regulations will undoubtedly become more restrictive with time. Forty-five per cent of the energy requirement of North America is supplied by oil. It is assumed that a large percentage of Canadian-American energy requirements will remain oil-oriented for the next 30 to 50 years. It is vitally important that processes be devised for purifying and upgrading the heavy low-grade oils as quickly as possible to permit an orderly and balanced utilization of our fossil fuel resources.

(3) Relation to Other Branch Activities

The Petroleum Processing and Catalysis Research sub-activity has preparation facilities and laboratories for limited feed and product analysis and evaluation. The complete analysis requirements are supplied as a service by the Oil and Gas Laboratory and the Solid Fuel Analysis Laboratory.

(4) National Need

Canada, at present, has large reserves of all grades of oil. For economic reasons the fuel requirements are now supplied by the high quality crudes. However, the demand is increasing rapidly and for an orderly and economic use of our fuel resources, a proportionate amount of the lower grade reserves should be used. Transportation which requires light, high quality fuels demands a large percentage of our oil supplies (64% in U. S.) and this demand is increasing rapidly. The residual fuel oil market is also growing at a high rate. Therefore, the high quality crudes should be reserved for transportation demands and the lower quality reserves should be utilized for the residual fuel oil market. This therefore demands that techniques be developed for economically processing the heavier low-grade deposits to produce residual fuels that will meet future air pollution requirements.

(5) Alternatives

The alternatives are either to "high-grade" the known reserves and hope that the technology will evolve for processing the low quality deposits. or use crude stripping and coking techniques to refine the poorer reserves. The first alternative runs the risk of depleting the richer hydrocarbon fields with no guarantee of replenishment, and the second would be a gross waste (butchery!) of the resource.

(6) Criteria

The major U. S. oil companies are working on the problems too and are, undoubtedly, making progress. The difficulties arise when Pollution Control Boards, Conservation Boards, etc., are required to rule on permissive limits on the use and processing of fuels. Independent investigation facilities must be available to all governing agencies to provide a basis upon which decisions can be made.

(7) Preferred Course of Action

To minimize the extent of air pollution caused by the burning of fuel oils the research effort should be concentrated on the removal of impurities and potential pollutants before combustion. In the long term it will be easier to process a small volume of fuel oil than a large volume of combustion gases. Because cost is such an important factor, large scale support should be provided for the development of the engineering techniques required.

(8) Project Titles and Technical Objectives

The objective is to devise improved techniques for removing contaminants and refining to produce a cleaner, better burning oil. It was decided that hydrogenation was the best means of accomplishing these objectives and industry must concur as there is an accelerated interest in this process. All types of hydrocracking and hydrogenation procedures are being investigated on both bench and pilot plant scale.

a) Bench Scale Evaluation of Catalysts and Catalytic Processes for Removing Impurities from Heavy Fuel Oils

The objectives are (1) Improved techniques for refining low-quality crude oils by low pressure hydrogenation schemes. The low pressure approach was chosen as, from an economy standpoint, industry will not consider high pressure procedures at this stage of development.

The bench scale program operates in advance of the pilot plant research with a view to charting the course for the larger scale experiments to follow. Four rigs are in operation on various problems and two are automated for continuous catalyst life testing experiments. Catalyst activity and life is studied along with methods of minimizing gas losses and coke formation.

(2) Improved catalysts for refining heavy fuel oils—low-grade residual oils contain metallic impurities (and frequently clay and mineral matter) which poison or promote coking on the surface of conventional catalysts and seriously reduce their effectiveness. The experimental program in this project is concerned with the development of long-lived species of catalysts specifically resistant to the coking and tarring of the asphaltic fractions. At

the present time the emphasis is on the development of low-density catalyst forms for liquid phase hydrogenation and hydrocracking.

b) Pilot Plant Scale Catalyst Slurry Hydrogenation Process

The objective is to determine by continuous pilot scale experiments the product quality and yield and the catalyst activity and life when refining low-grade crudes and bitumens. As the feed material is very likely to contain metal contaminants and mineral matter, which would poison and plug the pores of conventional pelleted catalysts reducing their activity, the slurry process using inexpensive powdered catalyst was chosen for this work. Mineral matter along with spent catalyst can be continually removed and replaced with fresh catalyst while the plant is in operation. Any range of pressures can be tested up to 10, 000 psi. The oil industry is keenly interested in this procedure.

c) Pilot Plant Scale Fixed Catalyst Bed Hydrogenation Process

The Fuels Research Centre has a facility for testing the refining of crude oil fractions or coker distillates by continuous fixed bed pilot plant scale experiments. The hydrodesulphurization of oils has been thoroughly studied using this process and the effect of the operating variables, pressure, temperature, throughput and catalyst studied. This process is used for final refining of preheated crude oils.

d) Gaseous Fluid Bed Processing of Heavy Fuel Oils

The objective is to provide reliable data for predicting the behaviour of catalysts and Canadian charge stocks in commercial fluid catalytic cracking units, but requiring only small amounts of feed stock, catalyst and manpower for operation. The equipment is capable of operating at pressures up to 1500 psi which will permit investigation of hydrogenation reactions in a fluidized catalyst bed. The unit has both a once-through batch catalyst circulation system and a continuous catalyst recirculation and regeneration system. This is the only pilot plant in existence in Canada capable of conducting pressure, fluid hydrocracking experiments and it will assist in the development of Canada's large bituminous sand and low-grade crude areas.

e) Distillation

The processes of separation of hydrocarbon material into simpler products form the "backbone" of refining technology. Distillation is the principal separation process. Not only is distillation used to obtain the primary or virgin petroleum products, it is also used to prepare feed stocks for, and recover secondary products from, thermal and catalytic conversion processes. It acts as a support project for the other work of the Petroleum Processing sub-activity and is an absolute necessity in this regard.

In addition, research will be carried out:

1) To determine the efficiency of column internals and ancillary components with varying percentages of mineral matter in low-grade crude oils, bitumens and residues.
2) To increase the efficiency of the distillation process by improved design of the column and ancillary equipment.

(9) Projected Costs and Scheduling

	Man Yrs/Yr			Cost/	Total/
	72/73	73/74	74/75	Man Year	3 Years
Professionals	12	15	15	15,000	630,000
Technicians	12	14	14	8,000	320,000
					950,000
Plant, service and overhead					930,000
					1,880,000

(10) Benefits

The development of new and improved processes and equipment for upgrading Canadian low-grade hydrocarbon reserves to meet the demands of both air pollution regulations and resource utilization and conservation requirements.

(11) Input and Output

It is difficult to place a dollar value on the research. The resource is extremely large and even a fractional per cent improvement in recovery runs into millions of dollars per year. The value of an improved basis for air pollution control and regulation is also impossible to assess.

(12) References (Examples only)

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15. Hydrogenation of Coker Distillate Derived from Athabasca Bitumen; A. R. Aitken, W. H. Merrill, M. P. Pleet, The Canadian Journal of Chemical Engineering, October 1964.

16. Vapour Phase Stripping of Lloydminster Crude Oil in a Sloping Plate Distillation Tower; F.L. Booth, R.E. Carson and D.S. Montgomery, July 1961.

17. Low Pressure Hydrodesulphurization of Coker Distillate from Athabasca Bitumen; F.L. Booth, R.E. Carson, K.W. Bowles, D.S. Montgomery, February 1958.

SUB-ACTIVITY 2: EVALUATION OF FOSSIL FUELS

Objective

"To assess fossil fuel resources".

Sub-Sub-Activity 1: Service, Liaison and Consultation

Objective

"To provide government, industry and public with scientific and technical advice and service related to the quality of Canada's oil and gas resources".

(1) Situation

Certain services are maintained for the protection of the mining industry, such as the analysis of mine air for explosive and toxic gases. This service provides the mining inspectorates of the provinces with a means of ensuring that the monitoring apparatus is up to standard, and enables toxic gases, such as aldehydes and oxides of nitrogen to be determined, for which there are no other available monitoring methods.

The FRC Oil and Gas Laboratory plays a primary supporting role for all the research work on hydrocarbon processing. This involves the quantitative measurement of numerous hydrocarbons and other substances for material balances, and the measurement of physical properties for the characterization of the products produced.

As an aid to industry and to assist other government laboratories, this laboratory participates in the cooperative exchange of samples.

Due to the special expertise available on naturally-occurring oils and refined products, samples of water contaminated by hydrocarbons or earth samples similarly contaminated are analyzed when the federal government is involved in litigation, or as an assistance to the provinces or municipalities.

Associated with the atmospheric pollution programs, survey work is conducted of the sulphur content of crude oils and refined products.

(2) Planning Assumptions

The Fuels Research Centre, over the years, has built up extensive analytical facilities for gaseous and liquid hydrocarbons. This facility involves over $100, 000 worth of specialized equipment, and the trained personnel to operate it. It is planned to maintain and improve the capabilities of this unit so that the research activities receive adequate support, and, in addition, to ensure that the pollution programs can properly identify a wide range of toxic compounds. This means that a much wider range of gas analysis, chromatographic, and mass spectrographic equipment is necessary than would normally be associated with the petroleum refining operations, or the analysis of mine air. The extension of the gas analysis capability to include the high molecular weight carcinogenic compounds is therefore planned.

The growth of large cities in Canada indicates that far more attention will have to be devoted to the total level of contamination coming into the area. This means that the total quantity of petroleum products consumed in the area, and their sulphur content, has to be determined to provide a basis for dispersion calculations. More attention will be devoted to the assessment of the quality of the fuel oil and diesel oil consumed in large urban centres, and less emphasis will be placed on gasoline surveys.

(3) Relation to Other Branch Activities

The relations of this sub-sub-activity are more closely linked with the provincial agencies, such as all the provincial mining inspectorates, the Alberta Oil and Gas Conservation Board, the Ontario Department of Energy and Resources Management, the Canadian Government Specifications Board Committee on Petroleum and Associated Products than with the other Divisions of the Mines Branch, though special gas analyses are conducted to aid the Steel Castings Institute in their study of molding sand binders.

(4) National Need

Gas analyses for low molecular weight toxic gases, commonly associated with the use of diesel engines and explosives in underground workings, are required to ensure adequate safety levels are maintained throughout the nation. It is also essential that the concentration of methane be maintained below the lower explosive limit. As the provinces at this stage in their development cannot afford the cost associated with the building up of extensive facilities for gas analysis and their operation, this service must be supplied at the national level.

(5) Alternatives

The rapid developments in the technique of mining, i.e., the use of ammonium-nitrate fuel oil as an explosive and underground dieselization of motive power, as well as the growing diversity of pollution problems in the urban centres, leave no alternative but to constantly improve the analytical instrumentation to cope with the growing number of problems. Research on instrumentation, methods of analysis, and sampling are essential to keep pace with the requirements of the various regulatory agencies.

(6) Criteria

The criteria used to assess the capability of the facility are based on the speed and effectiveness with which it can support the other research activities of the Fuels Research Centre, and upon the capability of the laboratory to maintain its advanced position in the field of gas analysis on difficult problems that cannot be resolved elsewhere in the country. Problems in this category include the detection of trace quantities of residual products of explosives in aircraft wreckage.

(7) Preferred Course of Action

The preferred course of action is to continuously improve the instrumental methods of analysis. This involves research on detection systems, fractionating methods, and the accumulation of experience in the field of petroleum chemistry to permit the interpretation of the data obtained.

(8) Project Titles and Technical Objectives

a) Mine Air Analysis

The objective is to improve current methods of sampling and analysis of mine air and diesel exhaust.

b) Hydrocarbon Analysis for Pilot-Plant Performance Evaluation

The control analyses for pilot-plant operation are done, as far as possible, by the pilot-plant staff. The analytical laboratory is required to make more complete assessments for material balances, and product quality evaluation, after the operating conditions have been stabilized.

c) Cooperative Exchange Analysis

As the oldest government laboratory engaged in hydrocarbon analysis, this laboratory has assisted in the setting up of the other Federal Government petroleum laboratories, and has encouraged the exchange of samples with industry and government agencies to maintain a high standard of uniformity throughout Canada.

d) Hydrocarbon Pollution of Air and Water

To expand information on characteristics types of petroleum products, the influence of oxidation, migration and solubility in water, and to interpret data acquired on contaminated samples received.

e) Surveys of Sulphur Content of Canadian Commercial Fuels

This project is designed to provide a basis for evaluating the total air pollution generated in the major centres of Canada. It will fit in with detailed studies of plume dispersion from the stacks of major power stations, in that it will provide an estimate of the background contamination.

(9) Projected Costs and Scheduling

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	2	2	2	15,000	90,000
Technicians	1	1	1	8,000	24,000
					114,000
Plant, service and overhead					72,000
					186,000

Sub-Sub-Activity 2: Evaluation of Petroleum and Natural Gas Resources

Objective

"To evaluate the quality of Canada's oil and gas resources to provide a basis for efficient utilization and control of pollution".

(1) Situation

Canadian natural gas and petroleum resources are very extensive, and provide about 75 per cent of the Canadian energy requirements. No other federal agency is charged with the national responsibility of evaluating the quality of Canada's natural gases, crude oils, bitumens, and oil shales. This quality assessment is essential for future planning for domestic use, export markets, defence posture, and for planning associated with the control of pollution within acceptable limits.

(2) Planning Assumptions

The extensive drilling in Canada's Arctic regions will undoubtedly expand the number of samples requiring analysis. The problem associated with the quality assessment of the crude oils and naturally occurring hydrocarbons is to organize the information in a manner that the maximum amount of geochemical information can be extracted. This is essential to avoid unnecessary drilling. The information must also be capable of being marshalled to indicate how much potential natural gasoline, diesel oil, jet fuel, and furnace oil is available. This requires card-sorting techniques and a refinement of systems of marshalling data to suit different requirements.

New analytical methods will have to be developed to secure more rapid means of determining the molecular-weight distribution of crude oils. These will probably be based on high-pressure liquid chromatography.

(3) Relation to Other Branch Activities

This function is not related to other activities of the Branch.

(4) National Need

Many aspects of gas analysis are required to supply the needs of the nation. There is a need to know firstly, the composition of the gas in the major reservoirs, and, secondly, the composition of the gas in the major pipelines.

The requirement for helium-resource evaluation for Canada's atomic energy program demands periodic analysis of gas from new formations to determine whether this gas should be added to the pipeline gathering system, or treated to have the helium removed.

The need to evaluate the quality of the crude oil resources is essential for future planning for domestic use, export markets, defence posture, and to provide a basis for judging the magnitude of the pollution problems of the future.

(5) Alternatives

Canada's recoverable reserves of crude petroleum and natural gas are increasing, but they are not unlimited. The seriousness of shortages of indigenous crude oil on Canada's balance of payments, leaves no alternatives other than to follow carefully the decline in quality of Canadian resources of petroleum, and to encourage the development of the low-grade heavy oils through research.

(6) Criteria

The criterion used to judge the effectiveness of the resource-evaluation program is that it must be up to date. There is little interest in the composition of petroleum burned in the past, or in depleted reservoirs. It is essential that the resource information be comprehensive and current. Serious obstacles have confronted this project in the past in the form of reductions in the complement of personnel arising from various economic "freezes".

(7) Preferred Courses of Action

A preferred course of action would be to reinstate the technical positions necessary to accelerate the analysis and processing of the data to offer more timely information to the public; the improvement of the analytical procedures and the classification of the information in a form that would be more readily used. Past evaluation methods of crude oil have been based on the availability of good crude oils. However, Canada is faced with the problems of evaluating low-grade crude oils with a large content of foreign atoms. Better methods are required to characterize these oils in relation to current and future refining technology.

(8) Project Titles and Technical Objectives

a) Natural Gas and Helium Evaluation

This project involves the analysis of natural gases for hydrocarbon species as well as the sour and inert gases; the necessary field work to ensure that the samples are representative and that the geological information and location are correctly represented; the marshalling of the data in a form that will facilitate sorting and correlation of the various properties of the gases that are of particular importance to specific types of utilization. The technical objective is to secure the basic technical data characterizing the Canadian natural gas resources in a form that may be used by industry and government for future planning. To carry out this essential function, continuous research to improve the analytical methods for isolating and characterizing the various gaseous compounds is required.

b) Crude Oil Quality Evaluation

This project runs parallel to that involving the natural gases with the exception that the problems involve liquid hydrocarbons. Characterization of these liquids by chemical compounds is not possible owing to the extremely large number of compounds present. Consequently, an inspection type of analysis has to be performed. The technical objective is essentially the same as that mentioned in (a) but the number of characteristic parameters is much larger.

c) Heavy Oil, Bitumen, Vein Hydrocarbons

This project involves analysing the heavy oils and bitumens of Canada. The technical objectives fall into three categories: characterizing heavy oil and bitumens as an aid to pilot plant processing, characterizing these substances in a manner which has the greatest possible significance from a geological point of view and, finally, characterizing these materials in a manner that will correctly indicate their future industrial potential.

A typical example of this type of work was the analysis of the Melville Island tar sand samples in support of Dr. Trettin's geological study of this resources.

d) Oil Shale Evaluation

This project again is similar in its technical objectives to those listed in (c) with the exception that no pilot plant research is being done on this class of material at the present time and, therefore, there is no need to characterize these substances from this point of view.

(9) Projected Costs and Scheduling

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	3	4	4	15,000	165,000
Technicians	7	11	11	8,000	232,000
					397,000
Plant, service and overhead					422,000
					819,000

(10) Benefits

It is difficult to estimate the value of the benefits resulting from the accumulation and dissemination of the data characterizing Canada's hydrocarbon resources. From the point of view of the potential export market for these natural resources in the United States it is vital to know not only the quality of the commodity for sale, which is supplied by the company concerned, but to have a background of information to permit predictions concerning the decline in the quality of the resources generally and to enable an estimate to be made of the future value of a resource of a given quality.

(11) Estimate of Input/Output of Research Projects

As there is no way to estimate the benefit in quantitative terms, no meaningful value can be secured for the Input/Output ratio.

(12) References

1969

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Analyses and Characteristics of Oil Samples from Quebec; Mines Branch Information Circular IC 216, R. P. Charbonnier, R. G. Draper, W. H. Harper and A. Yates.

Analyses and Characteristics of Oil Samples from British Columbia and Northwest Territories; Mines Branch Information Circular IC 220, R. P. Charbonnier, R. G. Draper, W. H. Harper and A. Yates.

Analyses and Characteristics of Oil Samples from Manitoba; Mines Branch Information Circular IC 221, R. P. Charbonnier, R. G. Draper, W. H. Harper and A. Yates.

Analyses and Characteristics of Oil Samples from Ontario; Mines Branch Information Circular IC 228, R. P. Charbonnier, R. G. Draper, W. H. Harper and A. Yates.

1970

Analyses and Characteristics of Oil Samples from Saskatchewan; Mines Branch Information Circular IC 231, R. P. Charbonnier, R. G. Draper, W. H. Harper and A. Yates.

Analyses and Characteristics of Oil Samples from Alberta; Mines Branch Information Circular IC 232, R. P. Charbonnier, R. G. Draper, W. H. Harper and A. Yates.

Sub-Sub-Activity 3: Solid Fuel Analytical Evaluation

Objective

"To develop analytical methods for the evaluation of solid fossil fuels and maintain a national reference laboratory for Canadian fossil fuels".

(1) Situation

Analyses are carried out on Canadian solid mineral fuels in order that they may be classified and evaluated for use. The analytical methods used are those standardized by North American (ASTM) and international bodies (ISO). Analytical results are used to catalogue and evaluate coals from all areas of Canada.

(2) Planning Assumptions

The rapid growth of coal markets, as indicated by coal contracts valued at $2 billion, assures increased activity in exploration and evaluation of this resource. This activity will undoubtedly place new demands on the analytical facilities and will necessitate the improvement of methods of evaluation for more diversified and sophisticated industrial requirements.

(3) Relation to Other Mines Branch Activities

Where required, analytical work is carried out to support the programs of the Division and the Mines Branch because of the special skills and facilities available.

(4) National Need

Canada has large reserves of high quality coking coal in western Canada and, in order to assess these resources to encourage efficient utilization, it is essential that investigational work be undertaken by a national government agency to ensure uniformity and that evaluation techniques of high quality are used. Experience has shown that it is essential to have the records of the evaluation kept by a central government agency as otherwise they can become dispersed.

This laboratory is the national reference laboratory for solid fuels and is unique in the federal service.

(5) Alternatives

Due to the rigid standards of analysis required and the special tests that are necessary to characterize coals, commercial laboratories are not capable of undertaking this type of work but will only carry out control analyses. The development of new methods of analysis and participation in international standardization bodies is also beyond their capability.

(6) Criteria

The selection of projects is governed to some extent by the consensus of international opinion in the major standardization bodies, ASTM and ISO, as to the specific areas that require research to improve the characterization of coal for international coal markets.

The demands arising from utilization specifications call for continuous revision of analytical methods and techniques to supply a wide range of analytical data with increasing speed and accuracy.

(7) Preferred Course of Action

Is to maintain the position of the laboratory in the international standardization bodies to ensure the accurate characterization of Canadian produced coal and that the classification boundaries do discriminate against Canadian coals.

It is desirable to conduct research associated with present and potential utilization requirements and to develop the laboratory facilities to be of effective service to the pilot plant studies conducted in the Fuels Research Centre.

(8) Project Titles and Technical Objectives

a) Research and Development of Methods of Analysis for Coal and Coke

Many methods of analysis become obsolete with advances in technology and must be up-dated and brought into line with modern concepts.

(i) Instrumental techniques to replace classical slower methods.
(ii) Need for more rapid and accurate techniques requires development of new methods for Proximate, Ultimate and Ash analysis.

b) Cooperative Coal Analysis Exchange Programs

To ensure a high standard of analytical methods in laboratories carrying out coal analyses.

(i) Canadian Co-op Coal Analysis Exchange.
(ii) U.S. Co-op Coal Analysis Exchange.

(9) Projected Costs and Scheduling

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	3	4	4	15,000	165,000
Technicians	4	8	3	8,000	160,000
					325,000
Plant, service and overhead					311,000
					636,000

(10) Benefits

a) Research and Development of Methods of Analysis for Coal and Coke

The main benefit is the assurance of an unbiased national laboratory with the facilities and expertise required to uphold Canadian interests in fields of international standardization.

b) Cooperative Coal Analysis Exchange Programs

The benefits of this project are to ensure the highest possible standards in analytical work by this laboratory and to provide a reference for commercial and industrial laboratories.

(11) Input and Output Estimates

N/A

(12) References

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7. Ibid - IC 147, 1963.
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10. Ibid - IC 182, 1966.
11. Ibid - IC 193, 1967.
12. Ibid - IC 208, 1968.
13. Ibid - IC 224, 1969.
14. Ibid - IC 249, 1970.

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16. Montgomery, W. J., "Summary of Activities Solid Fuel Analysis Section 1907-1958", Fuels Division TM 57/58 SF, 1958.

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Sub-Sub-Activity 4: Dust Explosibility Research

Objective

"To prevent or reduce dust explosion hazards and prevent the formation of excessive concentrations of respirable dusts which may be both toxic and explosive".

(1) Situation

In the interests of safety in industries involving combustible dusts (mining, quarrying, milling, etc.) and as a result of inquiries by individuals and specific requests by provincial departments of mines, a laboratory study of the explosibility of coal dusts was started in 1948. Between 1948 and 1957 intermittent routine testing was carried out on coal mine samples. For 1957 the scope of the project was enlarged to include all combustible dusts likely to be involved in dust explosions. Included in these dusts were dusts from base metal mines, agricultural processing, and forest products. Some research has been carried out on flame suppression of explosives. Work is carried on in the field of free silica determinations in mine dusts.

(2) Planning Assumptions

Each phase of these studies was prompted by inquiries from industry and mines for assistance in solving urgent problems relating to explosions. From the point of view of health hazards, work is also undertaken to estimate the free silica content of mine dusts which involves particle size distribution studies and means of determining particle size of ultrafine particles.

(3) Relation to Other Division Activities

The combustion of solid and liquid fuels creates air pollution problems in the form of fly-ash and carbon particles. Particle size studies are undertaken in this connection.

(4) National Need

The current emphasis is on safety and air and water pollution control. Much experimental work is needed to give indications of the steps necessary to prevent or reduce explosion hazards, and prevent the formation of excessive concentrations of respirable dusts which may be both toxic and explosive.

Studies of what constitutes sources of ignition will give indications of how these sources may be eliminated or reduced.

(5) Alternatives

If the facilities for such test work were not available in the federal government, it would be necessary to go outside the country for the required information. It is possible that a foreign government would not be interested in providing such services thus leaving a void in sources of information in this field.

(6) Criteria

As safety in mines and industry is a provincial matter, research in the field of dust explosions can only be undertaken on special requests by the industry. However, provincial governments are not equipped to handle such research projects.

(7) Preferred Course of Action

As the staff shortage will not permit extension of the present approach, i. e., solving ad hoc problems, it will be necessary to serve the public as required. If, in the future, funds become available and the need for such research more urgent, it should then be expanded to a full scale project.

(8) Project Titles and Technical Objectives

a) Coal-Dust Explosibility (3) (4)

Up to 1950 very little work in this field had been carried out in Canada. At this time sampling and explosibility testing was undertaken on mine dusts from eastern and western Canada.

(i) by studying the mechanism of coal dust explosions related to moisture and volatile matter.
(ii) by studying individual coals and assessing their explosibility.

b) Explosibility of Dusts Produced in Metal Mines (5)(6)(7)(8)(9)(10)(11)

In 1960 and before, base metal mines of the Noranda area, Quebec, experienced dust explosion problems and requested assistance in assessing the problem.

Work was undertaken, reports written and recommendations made. A simple test (12) was developed for use by the mines to predetermine dangerous areas prior to mining.

c) Explosibility of Metal Powders

In 1961 requests were received for explosibility testing on atomized aluminum and aluminum alloy powders. Work on this project is undertaken and reports issued.

d) Explosibility of Organic Dusts

Intermittent inquiries in the explosibility of organic dusts have been received covering agricultural milling operations, peat drying and grinding and wood grinding and drying.

The ad hoc assignments are undertaken, the work completed and reports written (14) or the results forwarded in letter form.

e) Flame Suppression of Explosives

There are three conditions necessary for an explosion to occur; if any one of the three are lacking, no explosion is possible.

The three conditions necessary are:

(1) a combustible or oxidizable material (fuel).
(2) an atmosphere which will support combustion (oxygen in air).
(3) a source of ignition (heat, flame, spark, etc.).

Many operations underground necessitate the production of fine combustible dusts which cannot be readily reduced if commercial rates of mining are to be achieved. The presence of sources of ignition provided by explosives is also essential to the mining operation. It is therefore essential to determine the explosive limits of the combustible dust and to design the mining conditions so that the operations are conducted outside these limites.

A preliminary report (13) on this work was written.

f) The Determination of Free Silica in Mine Dusts

As result of requests from provincial authorities, investigations were made of methods for the determination of free silica in dusts by both physical (microscopic) and chemical means.

Analyses are made on samples submitted and reports issued.

(9) Projected Costs and Scheduling

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Technicians	1	1	1	8,000	24,000
Plant, service and overhead					37,000
					61,000

(10) Benefits

a) Coal Dust Explosibility

Much research has been carried on in other countries of the world on coal dust explosions and their prevention. Canadian coals and mining conditions vary in many respects and are not strictly comparable. It is reasonable therefore that Canadian coals should be studied with a view to assisting the industry in explosion prevention.

b) Explosibility of Dusts Produced in Metal Mines

Work in this field was undertaken to assist the mines in preventing or reducing explosions causing considerable damage and material loss. The work so far undertaken has accomplished this objective.

c) Explosibility of Metal Powders and d) Explosibility of Organic Dusts

This work assists the various industries involved in preventing explosions and resulting fires and often death or injury. Each problem is considered on its own merits and consultations or experimental work undertaken to solve the problem.

e) Flame Suppression of Explosives

It is felt that this project may be of value as a low-cost means of preventing ignitions which might otherwise occur.

f) The Determination of Free Silica in Mine Dusts

To assist mine inspectors in evaluating the probable health hazard of respirable dusts produced at a given location and time in mining or quarrying operations.

(11) Input and Output

N/A

(12) References

1. Montgomery, W. J., "Comparative Explosibility of Dusts", Divisional Report FMP 62/36 SF (1962).

2. Montgomery, W. J., "A Comparison of the Explosibility Characteristics of Some Canadian Coal Mine, Base Metal Mine and Industrial Dusts", Mines Branch Investigation Report IR 61/68 (1961).

3. Montgomery, W. J., "Preliminary Studies on Dust Explosibility of Canadian Coals", Fuels Division DR FMP 82/59 SF (1959).

4. Montgomery, W. J. and Behnke, G. C., "Dust Explosibility Tests on Canmore No. 4 and Upper Marsh Seam Coals", Fuels Division TM 78/58 SF (1958).

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14. Montgomery, W. J. and Behnke, G. C., "Explosibility of Wood Dusts, Sogefor Ltd.", DR FRC 69/63 SF.

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Sub-Sub-Activity 5: Evaluation of Coal Resources

Objective

"To classify and evaluate Canada's solid fossil fuel resources to permit their efficient utilization".

(1) Situation

In spite of the recent history of contraction of the coal industry in Canada, coal continues to play an important part in the country's economy. The future is expected to bring new prosperity to the industry through the growing demand for coal, particularly in the energy and metallurgical markets. To aid industry in this role continuous evaluation of the quality of presently known reserves as well as evaluation of unknown or untapped reserves is essential to the rational utilization of this non-renewable resource. Rational utilization also implies awareness of the ever increasing need for environmental management.

(2) Planning Assumptions

New demands will be put on the coal industry for the exploration and development of new reserves of coal. These known reserves are in general of inferior quality and, because of mining methods geared to maximum output, selection at the coal face will be almost impossible. Knowledge of the quality of the coal "in situ" and its beneficiation characteristics are essential to a resource evaluation program associated with the increasing practice of selection of mining areas and surface beneficiation of coal to produce a custom product to rigid specifications.

(3) Relation to Other Mines Branch Activities

The qualitative evaluation of coal resources is directly related to Mines Branch activities concerned with energy resources, metallurgical reduction, environmental management, gasification and synthetic liquid fuels.

(4) National Need

The qualitative evaluation of Canada's coal resources and interpretation of the quality in terms of utilization criteria is regarded as basic in planning and forecasting of the country's economic future; it is regarded as an invaluable aid in maintaining and expanding markets for Canadian coal.

(5) Alternatives

There is no other national agency responsible for this qualitative evaluation as witnessed by the continuing requests for advice and data from industry (electrical, metallurgical, transportation, etc.), individuals, and government agencies such as the National Energy Board, the Department of National Defence and the Canadian Specifications Board.

(6) Criteria

The selection of projects is largely dictated by an assessment of the present and future industrial requirements for coal, nationally and internationally. This involves a knowledge of the process requirements for thermal electric power, metallurgy, environmental management, gasification and synthetic liquid fuel production.

(7) Preferred Course of Action

The preferred course of action is to increase the staff and facilities to enable continuation and expansion of the evaluation of Canadian coal resources in terms of future utilization needs to the degree that delays are not encountered and important markets lost because of lack of essential information on coal quality.

(8) Project Titles and Technical Objectives

a) Physical and Chemical Evaluation of Canadian Coal Seams

The objective is to evaluate and catalogue the geology, quality and potential of coal seams.

b) Evaluation of Canadian Coal Products

The objective is to evaluate, catalogue and publicize the characteristics of mined and prepared products from Canadian coal mines emphasizing the utilization criteria.

c) Beneficiation of Coal Resources

The objective is to utilize laboratory, pilot plant and industrial techniques and facilities to effect beneficiation of mined coal.

(9) Projected Costs and Scheduling

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	1/2	1/2	1/2	15,000	23,000
Technicians	1	1	1	8,000	24,000
					47,000
Plant, service and overhead					45,000
					92,000

(10) Benefits

As in the case of the hydrocarbon resources it is difficult to estimate the value of the benefits resulting from the accumulation and dissemination of the data acquired by this activity. From the point of view of the same of western Canadian coals to Japan and the United States, and a continental view now being taken of energy resources, it is considered essential to have accurate and impartial information properly related to the geography and geology of the particular area in which it is found.

(11) Input and Output

As the western coal resources now under contract amount to several billion dollars, and as this market is growing, it is important that impartial analytical information be available upon which to base export policy decisions. Although the total value of the coal under contract is known, it is extremely difficult to arrive at a meaningful estimate of the importance of authoritative and impartial estimates of coal quality. Therefore, we do not feel that a meaningful value of the input/output ratio can be secured for this activity.

(12) References

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14. Tibbetts, T. E. and Lloyd, T. A., "Evaluation of Coal Samples from Deister Table Project of Crows Nest Industries Ltd., DR 71/40.

15. Tibbetts, T. E., "Relative Strength Tests on Harmer Ridge Coal", DR FRC 71/39.

Sub-Sub-Activity 6: Evaluation of Peat Resources

Objective

"To improve and standardize methods of evaluating peat material, to improve methods of recovery and processing, to develop new uses of peat deposits and peat material".

(1) Situation

Canada has extensive resources of peat with large deposits in all provinces and territories. The area of peat bogs has been estimated in excess of 37,000 square miles, only a small portion of which has been mapped and surveyed. Of this only a fraction has been evaluated with respect to its potential for exploitation for agricultural, horticultural and other non fuel uses in view. Peat deposits are among Canada's least known non-renewable resources.

(2) Planning Assumptions

The peat moss industry in Canada is a relatively new industry and has experienced uninterrupted growth since World War II. The demand for peat products has largely been from the United States. It is expected that the demand for Canadian products will steadily increase due to improved products, educational programs expounding the benefits of peat usage, new uses and an improved competitive position in the United States market. This increased demand coupled with depletion of peat deposits presently being exploited necessitates continued evaluation of Canada's peat deposits.

(3) Relation to Other Mines Branch Activities

Insofar as peat is a non-renewable resource, investigations are related to the evaluation of resources of fossil fuels. The relationship within the Division is due to the original objectives of fuel resource evaluation and the Divisional continuity of peat has been preserved because of the continuity of expertise and staff associated with fossil fuel resource evaluation projects. With the exception of certain laboratory evaluations, peat resource investigations are dictated by different criteria of recovery, processing and utilization. Presently, the Division has one officer who devotes part of his time to peat science and technology.

(4) National Need

New market opportunities demand continual interest in Canada's peat resources. The present export value alone of packaged peat products is approximately $12 million, all to the United States. The industry, unassisted financially by governments, employs directly more than 1250 men in economically depressed areas of Canada in the recovery and processing of peat material; the livelihood of many others in these areas is undoubtedly dependent upon the successful and expanded exploitation of these peat deposits.

There is no duplication in Canada of the expertise and facilities for resource evaluation provided by this Division as witnessed by the many requests from provincial governments, industry and individuals for advice and assistance in peat deposit evaluation and technology.

(5) Alternatives

The alternative to federal government evaluation of the non-renewable resources of the country is to leave the responsibility of acquisition of this basic information to private industry and/or provincial governments. The shifting of responsibility is no solution to the national problem which requires the building of technical competence in the industry. This requires training, dissemination of information on new advances made in Europe and their adaptation to Canadian conditions. Finally it is essential to stimulate domestic research by showing research leadership.

(6) Criteria

Because of a highly competitive marketing situation the peat industry is not in a financial position to finance long-term research projects. Present marketing associations of the industry are not constituted for this purpose. Industry, for competitive reasons tends to secretively retain information pertaining to the value of peat deposits as well as to peat technology. In general, lack of experience and facilities hampers provincial governments in undertaking these projects entirely unassisted.

(7) Preferred Course of Action

The preferred course of action is to continue and expand the evaluation of peat deposits in Canada, carry out research directed toward (a) improvement and standardization of methods of evaluating peat material, (b) improvement in methods of recovery and processing and (c) new uses of peat deposits and peat material. Such a course of action would require a minimum staff of one scientist and one technician.

(8) Project Titles and Technical Objectives

a) Evaluation of Peat Resources

The objective is to systematically catalogue the occurrences, reserves and quality of peat deposits in Canada.

b) Development and Standardization of Methods for Evaluation of Peat Resources

The objective of this project is to improve the accuracy of present parameters and develop new ones for evaluating peat material in conformity with the criteria of utilization.

c) Uses of Peat Deposits and Peat

The objective is to improve efficiency of present uses of peat deposits and peat and search for new applications for the peat products.

d) Methods of Exploitation of Peat Deposits

The objective is to improve and develop methods of recovery (mining) of peat material and methods of processing including drying and packaging.

(9) Projected Costs and Scheduling

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	1 1/2	1 1/2	1 1/2	15,000	67,000
Plant, service and overhead					26,000
					93,000

(10) Benefits

The main benefits of the activity include (1) the making available of basic information concerning a non-renewable national resource, (2) improvement in evaluating procedures and (3) a contribution to the marketing of Canadian peat products.

(11) Input/Output

The peat industry is particularly important to the depressed rural areas of Canada. For this reason the Fuels Research Centre has maintained a small but continuous interest in this industry. At the present time it is difficult to evaluate the input/output of research in a quantitative manner, consequently it is not possible to make an estimate of the ratio.

(12) References

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Sub-Sub-Activity 7: Evaluation of Fine Structures

Objective

"To develop new methods of evaluating the physical structure of coal, coke and carbon and its relation to industrial utilization".

(1) Situation

The proper selection of coal and carbon for specific industrial purposes depends to a considerable extent upon its physical structure. There is, firstly, the micropore volume that plays the dominant role in questions of weathering and low temperature reactions, and secondly, the fine structure, which includes the features visible under the microscope that play a vital role in the selection of coals for metallurgical use. During the past five years an attempt has been made to build up the necessary facilities to give the required direction for the assessment of the physical character of coal and carbon. This requires a combination of petrographic and chemical tests. This skill is essential for interpreting the significance of various aspects of coal quality in reconnaissance samples and for explaining the different behaviour of coals having the same bulk properties such as volatile matter, fixed carbon and moisture.

(2) Planning Assumptions

The rapid growth of the market for western Canadian coking coal in Japan has greatly increased the demand for reconnaissance drilling and petrographic interpretations as to the suitability of a wide variety of coals for use in metallurgy. This has emphasized the importance of research on better methods of characterizing semi-fusinite, particularly in Canadian coals. The need to improve the existing facilities for this purpose is at hand. This means that new properties such as secondary electron emission and the degree of polarization after heating the semi-fusinite must be explored.

The transportation of coal by pipeline suggests that the microstructure will become of increasing importance in oil absorption, weathering, and the behaviour of oil wetting after the suspension of coal in water. These areas require extensive research.

(3) Relation to Other Mines Branch Activities

These studies of the fine structure of coal and coke are intimately related to the carbonization work in the Metals Reduction and Energy Group and are useful in defining the morphology and tecture of carbon products.

(4) National Need

The service supplied by this laboratory cannot be met by the microscopic and petrographic laboratories as the interpretations require the combination of physical and chemical tests associated with a great deal of background knowledge of the chemistry of coal, coke, and carbon forms such as graphite, and carbon black. This research unit provides important support for the Metals Reduction and Energy Group as well as playing a key role in the quality evaluation of Canadian fossil fuels. This service is also required by the Department of National Revenue in connection with the characterization of imported carbons.

(5) Alternatives

Projects within this activity might be changed, but to do without this activity would be a retrograde step setting the laboratory back to the position it held ten years ago and serioudly impairing its standing with other national laboratories. All the major contributors to ASTM have such a facility available to assist in the interpretation of the physical and chemical properties of coal and coke after they have been subjected to a wide variety of operating conditions in industry.

(6) Criteria

The criteria used to select projects are based upon (a) industrial demand, (b) experience and knowledge of the chemical structure of coal and the relative importance of certain physical and chemical properties in processing, and (c) consideration of the fundamental properties and their association in coal and coal products.

(7) Preferred Courses of Action

The preferred course of action is to develop new methods of evaluating coal, coke and carbon properties. The study of the electronic properties of coal macerals has already indicated that many entities can be identified by the secondary electron emission. This holds great promise for automatic quantitative scanning. This property is now being studied and it is proposed to extend this work.

The study of semi-fusinite properties is very important in relation to the development of western Canadian coal markets in Japan and understanding some of the problems associated with the production of fine coal for pipeline transport. This research must be sustained to give direction to the coal resource evaluation program.

As opportunities permit, the reactivity of coke will be studied to obtain more realistic parameters for judging coke quality.

(8) Project Titles and Technical Objectives

a) Coal Evaluation by Optical Microscopy

The development and standardization of optical microscopic techniques for quantitatively assessing the quality of coal will continue in association with the United States Bureau of Mines and the ASTM with the object of extending the methods now used for coking coal to low-rank coals including lignite.

b) Coal Evaluation by Electron Microscopy

The optical microscopic methods for characterizing many special aspects of coal will be largely obsolete in three years. New techniques have to be developed associated with the secondary electron emission of polished coal samples. The electron probe will also play a dominant role in the assessment of the mineral matter distribution. These new techniques have to be developed and adapted to coal in a manner that will permit international standardization.

c) Reactivity Test of Coke Anthracite and Chars

The assessment of the quality of cokes and chars as reductants is a complex problem. Areas which appear to require further research are those factors which give rise to the dust loss in blast furnaces and those associated with the reactivity of the carbon to gas and to molten iron oxide or calcium ferrite.

d) Weathering of Coking Coal

The slight oxidation which coal undergoes under atmospheric conditions has a deleterious effect on the coking properties of coal. Research is in progress to measure this deterioration in a quantitative manner.

e) Desulphurization of Petroleum Fluid Coke

The growing air pollution problems in the cities necessitate the desulphurization of petroleum feed stocks. Using present technology, this requires a greater production of high-sulphur content fluid coke. The problem is to find new techniques to desulphurize this material to the point where it is acceptable as a feed material in the metallurgical industry.

f) Research on the Characterization of Electrode Pitch

The type of coal carbonized and its degree of exposure to air influence tar quality and particularly the quality of the electrode pitch. The ability to measure the oxygen content of coal and coal tar opens up new avenues to assess the role played by oxygen in pitch quality.

(9) Projected Costs and Scheduling

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	1	1	1	15,000	45,000
Technicians	1	1	1	8,000	24,000
					69,000
Plant, service and overhead					54,000
					123,000

(10) Benefits

One of the direct benefits arising from improved techniques of coal quality evaluation is the saving in mining costs associated with opening up seams to secure large samples in the order of several tons of coal for pilot plant evaluation in the 500-lb charge test oven. Savings of thousands of dollars can be obtained if a more or less complete assessment can be made from diamond drill cores.

(11) Input/Output Estimates

Again it is difficult to give an accurate quantitative assessment of input/output ratio due to the difficulty in measuring the input and output. It is expected that considerable progress can be made in this activity within a year by the coal scientist.

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Sub-Sub-Activity 8: Research on Bituminous Substances

Objective

"To acquire basic knowledge of the chemical structure of Canada's low-grade crude oils and bituminous substances as an aid in the development of new refining technology and more efficient means of utilization".

(1) Situation

Basic knowledge of the chemical structure of Canada's low-grade crude oils, and bituminous substances, is required to aid in the development of new refining technology, and more efficient means of utilization. As the magnitude of these resources is of the order of 600 billion barrels, a saving of one cent per barrel is a very large sum. Little is known of the chemistry of the sulphur compounds except that the sulphur is largely involved in ring structures. Further information is required to find better methods of sulphur removal to reduce atmospheric pollution. Better knowledge of the chemical structure of asphaltic crude oils will also lead to a better understanding of weathering reactions responsible for the cracking of asphaltic pavements and the development of more non-fuel uses for specific classes of compounds. Another important aspect of the study of the chemical structure of heavy crude oils is that the chemical changes associated with maturation of petroleum indicate the geological regions where various types of petroleum may be found and where there is little prospect of finding any oil at all.

(2) Planning Assumptions

The construction of a 50, 000 barrel per day plant in the McMurray area of the Athabasca bituminous sands by Great Canadian Oil Sands Ltd. and the granting of a permit to Syncrude of Canada Ltd. by the Alberta government to proceed with the construction of an 80, 000 barrel per day plant is a strong indication that the development of Canada's vast deposits of low-grade crude oils is now taking place. Associated with this development there is still a great need for more detailed information on the chemical and physical properties of bitumen upon which to base rational designs for mining, transportation and refining equipment. Basic information of this type is essential to reduce the wastage of the resource and the creation of pollution problems for the future. The present plant of Great Canadian Oil Sands Limited wastes 500 tons of hydrocarbons per day in the form of coke and discharges to the atmosphere all the sulphur dioxide that the immediate region can stand. Another plant of this type cannot be tolerated in this region and therefore a different refining scheme must be developed by the Syncrude group. It is considered that more detailed knowledge of the sulphur linkages present in the asphaltene fraction and in the middle distillates is basic for this new development.

(3) Relation to Other Division Activities

Knowledge of the chemical structure of heavy crude oils and their molecular weight distribution is a fundamental requirement for the Petroleum Processing Activity.

(4) National Need

The Federal Government must look forward to the day when the reserves of high-grade petroleum are much less plentiful and much of the hydrocarbons supply must come from low-grade heavy oils and bitumen. This implies that much more chemical work will have to be done on these substances than was done in the past on normal crude oils which have high foreign atom contents. Industry has been reluctant to carry out this basic work and has tried to approach the problem using conventional techniques. This has cost Great Canadian Oil Sands very dearly. Even today this company is barely meeting the interest payments on the capital invested. It is in the interest of the Federal Government that there not be a series of failures in the development of this resource.

(5) Alternatives

If no research on the chemical structure of heavy oils were done, it would mean that the Petroleum Processing Group would have no new chemical avenues for refining developed for consideration at the pilot plant scale. It also would virtually isolate the Fuels Research Centre from the research meetings of the American Petroleum Institute where the current research on petroleum is discussed and the research policy of the API is developed. It is only through this work that contact with the North American petroleum industry as a whole can be maintained.

(6) Criteria

The chemical structure of petroleum is related to its geological situation and a knowledge of the organo-geochemistry of petroleum is an aid to the discovery of different types of petroleum. The chemical structure also has a bearing upon the production, refining, transportation, and utilization of petroleum. The criteria used in selecting projects are governed by considering the contribution of the project to each of the five areas mentioned.

(7) Preferred Course of Action

Many of the problems arising in the refining of petroleum are caused by the high molecular weight fraction of petroleum referred to as the asphaltenes. This fraction is also responsible for the mechanical properties of asphalt which plays a vital role in road building. Consequently, a certain fraction of the research effort must be concentrated on characterizing these substances.

The separation of the bitumen from the oil sand and much geochemical information can be secured by a study of the low molecular weight components and dissolved gases. Consequently, projects are undertaken in this area.

A considerable proportion of the sulphur-containing compounds are concentrated in the middle distillate fractions. As these compounds play a very significant part in refining and may potentially contain useful compounds for extraction, research projects are selected in this area to characterize this material more precisely. Better knowledge of the structure may lead to better processing techniques to avoid atmospheric pollution.

The study of the thermal energy changes associated with heating of asphaltene fractions, petroleum fractions, or crude bitumen, it essential to obtain accurate heat capacity data for the rational design of petroleum processing equipment. This same information can also give an insight into the chemical structure of these fractions. Research projects are therefore assigned in this area.

(8) Project Titles and Technical Objectives

a) Characterization of the Asphaltene Compounds of Bituminous Substances

The technical objective is to study the sulphur linkages in the asphaltenes by degradation techniques.

b) Characterization of the Sulphur Compounds in the Middle Distillate Boiling Range - Athabasca Bitumen

The technical objective is to isolate the compounds containing sulphur in the dicyclic aromatic class in Athabasca bitumen.

c) Characterization of the Low Molecular Weight Hydrocarbons in Athabasca Bitumen

The objective is to secure information that will be helpful in evaluating the losses that occur in the hot water separation process and to secure organo-geochemical information useful for exploration.

(9) Projected Costs and Scheduling

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	4	4	4	15, 000	180, 000
Technicians	1	1	1	8, 000	24, 000
					204, 000
Plant, service and overhead					106, 000
					310, 000

(10) Benefits

The magnitude of the resource of low-grade petroleum in Western Canada is very large, probably 1000 billion barrels, most of which is inaccessible as far as present day techniques of production are concerned. Small increases in the recovery obtained through a better understanding of the chemical nature of this material yield very substantial savings to the national economy.

(11) Input/Output Estimates

Quantitative evaluation of this ratio is not possible, yet it is obvious from the magnitude of the resource and the growing importance of oil in the world economy that considerable expenditures are justified to develop the technique of utilizing these resources.

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B - METALS REDUCTION AND ENERGY CENTRE

SUB-ACTIVITY 1: COAL BENEFICIATION RESEARCH

The goals and objectives are:

- to develop new methods of fine particle separation particularly using the cyclone separation apparatus.
- to develop new ancillary equipment to support the cyclone separation studies such as the pulp divider and slugging cyclone.
- to develop new methods of mechanically dewatering coal by oil assisted techniques for application to coal preparation plants or slurry pipelines as applied to coal transport.
- to develop integrated flow sheets of low capital and operating cost using the specially developed separating and dewatering equipment for special purposes such as pyrite removal from Cape Breton coals.
- to supply a supplementary mineral processing service to local western needs using coal-cleaning cyclones.
- to combine related studies in statistics of sampling theory, sink-float investigations, etc.
- to provide a sampling service for new coal prospects in Western Canada.
- to provide advice and consultation on sampling and coal upgrading procedures to the Canadian coking coal industry.
- to assist with the commissioning and testing of new coal-cleaning installations.

(1) Situation

The processing of granular raw materials such as coal, ores and industrial minerals poses certain problems, particularly with respect to the fine particles. The efficiency of gravimetric and granulometric separation requires continuing study as leaner ores and poorer coals are being mined owing to depletion of reserves. Refinement of processing techniques is called for in order to prevent or reduce pollution of the air, streams and the soil at the source.

(2) Planning Assumptions

The production forecast of coal consumption for power generation alone in Western Canada indicates a five-fold increase (from 4 to 20 million tpa) by 1978 (basis 1968). Added to this is an increase in production of metallurgical coal for export of approximately 10 million tpa by 1974.

(3) Relation to Other Mines Branch Studies

The Western Regional Laboratory activity is directly related to the Ottawa-based groups in that it receives support in chemical analytical work and provides to it sample for coking. The WRL also maintains relations with the Mineral Processing Division in that it receives technical information available in Ottawa on projects in hand with WRL; and provides information on the results obtained with specifically water-only gravimetric separations and generally other separations performed on ores and minerals in Western Canada, as required.

(4) National Need

The rapid increase in power generation and the consumption of coal and ores for metallurgical processes call for a commensurate effort in research and development at the Western Regional Laboratory and of technological support for industries introducing new equipment and new processes developed by the Western Regional Laboratory.

(5) Alternatives

There are two alternatives: firstly, research and development by industry for its own sake, and secondly, transfer of the activity of the Western Regional Laboratory to Ottawa. Neither one of the alternatives has the two main advantages of the present organization, namely, the central location of WRL in Western Canada, which facilitates direct contact with the mines; and the availability of new equipment and processes to the mining industry as a whole.

(6) Criteria

Ready availability of the results of research and development to the industry of Western Canada and elsewhere, in the form of publications, new equipment and new processes. Technological support in introducing new equipment and processes developed at WRL by direct contact with management and by task groups instructing operators in the use of new equipment, testing new installations and performing plant studies during change-over to new equipment and processes in existing plants.

(7) Preferred Courses of Action

Through continued contact with mine and plant management, conduct plant surveys, initiate studies of existing problems in the processing of fine particle fractions of coal, ores and minerals; conduct tests in laboratory and pilot plant scale in Edmonton; publish in technical journals, in divisional reports and by direct communication with mine management; install commercial-scale units of new equipment developed by WRL at existing plants and run them under actual plant conditions with a task group, aided by plant personnel as required; provide performance calculations for prospective installations (not yet built) on the basis of data obtained from previous installations elsewhere, using computer techniques; and provide unclassified technical information to those enquiring about application of equipment and processes.

(8) Project Titles and Technical Objectives

a) Fine-Particle Beneficiation of Ores and Waste Materials

Beneficiation flowsheets and equipment specifications for ores and waste materials requiring special study, as a direct service to industrial companies. Examples: barite tailings, sand deposit for fiberglass manufacturing, recovery of copper from shredded electric wire remnants, low-grade phosphorus deposit, etc.

b) Gravimetric Separation of Coal, Ore and Industrial Minerals

By water-only processes, using compound water cyclones in conjunction with pulp dividers, dual mix tank in automatic controlled two-stage circuit (three product separations), for the purpose of ash reduction and/or sulphur reduction of coal for metallurgical purposes and for steam raising.

c) Effluent Treatment and Slimes Disposal

Develop equipment and processes for the recovery of re-usable plant water from industrial waste water in order to reduce spillage of same in rivers, lakes, the sea; and thereby preventing pollution. One such piece of equipment is the slugging cyclone, which removes finely divided solids from dilute effluents in the form of semi-solid slugs for disposal with coarse reject, reducing or avoiding the need for slurry ponds.

d) Mechanical Drying of Coal Slimes with Slugging Cyclones Assisted by Oil

This process obviates the need for thermal drying of coal while eliminating air pollution of the latter, at generally lower cost, depending on the cost of oil. Application in coal washeries and for the long-distance hydraulic transport of coal (Cascade Pipeline Ltd.). Possible movement of coal to Eastern Canada.

(9) Projected Costs and Scheduling

Scheduling of projects to be done in close cooperation with industry, as dictated by need for plant surveys, R & D at WRL and technological support (task groups) in existing plants and in new operations during start-up, where WRL equipment and processes are used.

In five years' time it is expected that sufficient experience in Canada will have been obtained to substitute the activity in the field by written instructions based on information available from existing plants and installations.

Projected total costs (for salaries and equipment) are estimated to be approximately:

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	3	3	3	15,000	135,000
Technicians	6	6	6	8,000	144,000
Overhead					161,000
Total					440,000

The present staff includes 2 Professionals, 4 Technicians and 1 Clerk, and costs amount to approximately 75% for salaries.

(10) Benefits

Exceeding a benefit/cost ratio of 10:1.

(11) Input and Output Estimates

Example of One Project	Input	Output Over 4 Years	Benefit/Cost Ratio
Water-only preparation of coal	$350,000	$4,800,000	14:1

The R & D on the Compound Water Cyclone covers the years 1961-66, when a total cost of approximately $350,000 was incurred. During this period CWC installations were erected at three mines (Moura, Qld., Australia, 225 tph: Peabody-Utility Mine, Ill., 150 tph, two stage; and Coleman Collieries, Alta., 16 tph, desulphurization unit). The capital cost of these installations is approximately 45% or roughly one-half of the capital cost of conventional equipment. This reduces the total operating cost (approx. $0.22 per ton r.o.m. of which 40% or $0.09 is capital depreciation) by $0.09 for capital alone. Added to this, savings of eliminating magnetite for HM separation and reagents for froth flotation, the total reduction of water-cycloning versus HM cycloning plus froth flotation for coal preparation purposes, equals approximately $0. 20 per ton. The present installed capacity in operation is estimated at 1500 tph with a benefit of $1, 200, 000 per annum. Since 1966 the Development and Technological Support functions have increased as the introduction of Compound Water Cyclones began to develop; and as a result of this development new research projects have been initiated, in two joint projects with the Fuels Research Centre, Ottawa, namely on the desulphurization of coal, and on the oil-assisted mechanical dewatering of coal slimes.

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SUB-ACTIVITY 2: CARBONIZATION RESEARCH

The goals and objectives are:

- to evaluate new sources of coking coals at bench and pilot-plant scales including petrographic and chemical techniques.
- to devise improvements to the conventional coking process by means of development of pre-heating techniques (output gain of 40%) and the use of agglomerates or other additions such as coke breeze to lessen dependence on costly scarce coals.
- to develop entirely new coking processes of the form-coking type.
- to study interconnection of conventional and non-conventional coking to new coal up-grading methods.
- to develop the application of non-conventional coking methods to specific coke requirements (example is use of rotating hearth to service phosphorus industry).
- to perfect coal and coke testing equipment from laboratory to pilot-scale.
- to provide a consultative service to the Canadian metallurgical coal industry.

(1) Situation

The metallurgical industry, the largest consumer of coke, requires high carbon products manufactured principally from coking coals, to serve as reductants and sources of energy in pyrometallurgical processes.

The coke industry in Canada manufactures approximately 5 million tons of coke annually with a gross value approximately $100 million (exclusive of by-products). The Canadian coal industry produced 11 million short tons of coal in 1968 valued at 61 million dollars*. With new contracts for export coal to Japan, it is forecast that an additional 20 million tons of coking coal alone will be shipped annually to that country from Western Canada within the next five years, with an export value, FOB Vancouver, in the order of 300 million dollars per year. In 1969, Japanese contracts approximated 2 billion dollars worth of coal**.

This sub-activity serves, almost exclusively, the technological requirements of the coal and coke industries in Canada. The task is accomplished by seeking means of assisting the industries in the following manner:

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*Dominion Bureau of Statistics.

**"Report on Japan", The Financial Post, August 23, 1969.

(1) the coal industry in the exploration, mining, beneficiation transportation, utilization and quality control of Canadian coking coals;

(2) the coke industry in the improvement of coke quality, selection of coals for the manufacture of coke, the development of new techniques and the modification of existing processes for the production of high carbon products for specific markets.

(2) Planning Assumptions

The production of primary iron, the basic source of steel, is presently wedded to the use of coke manufactured by the carbonization of coking coals. It is inconceivable that other forms of energy can totally displace its use from the conventional iron blast furnace. In addition to supplying heat and reduction to the process, coke is a consumable refractory permitting the necessary bed permeability so desirable for efficient blast furnace operation. Other forms of energy have been applied to the blast furnace to supplement the heat requirements, to a limited extent, with a corresponding reduction in the coke rate. Some theorists claim that the coke rate is now approaching a theoretical minimum. Despite the reduction in the amount of coke required to produce a ton of hot metal (coke rate), the total coke consumption is increasing with the rise in the production of primary iron (1).

It is important that the coke-industry supply a product whose quality contributes to the increased technology and changing demands of the iron-making process; this is ultimately reflected in an over-all cost reduction to the integrated steel industry and an improvement in the quality of the end-product. The good coking coals are becoming more expensive and less available, with an increased incentive towards finding methods of utilizing marginal coking coals, previously unacceptable to the industry. Coke breeze and other forms of available carbon with unacceptable physical or chemical properties provide potential sources of additive material to coke oven charges if technology can demonstrate the techniques required to accomplish this feat and at the same time produce an acceptable product. The high capital cost of coke-oven plants (over $30 per ton-year) precludes the construction of new coke-plants except as a last resort. Three of the four integrated steel plants in Canada built new plants in 1968 valued in excess of 75 million dollars. These plants now find themselves in a position where their capacity is insufficient to meet the increased steel production required. Research is active, generally, on developing techniques for increasing the throughput from existing plants by preheating of coke oven charges, high density charges, high coke yielding coals that can be used safely in slot-type ovens, improved thermal conductivity of refractory oven linings, etc. (2). Non-recovery coke ovens are also returning to use for the production of supplementary coke for blast furnaces, for chemical processes and for foundry use. Their favour is related to low capital cost, the ability to "moth-ball" and start-up with ease, the present non-economic return on by-products from carbo-chemical processes and their ability to utilize expanding-type coals. Regarding non-conventional coke-making processes, form-coke is of international interest. This type of coke may be the most acceptable product of the future, as it lends itself to application of non-coking coals with a control of the geometry of the entity shapes which in turn is conducive to more efficient operation in metallurgical reactions (3). Studies are in progress in many organizations regarding the advantages of form-coke, and its commercial application. As yet form-coke is limited to specific uses and has not entered the blast furnace applications except experimentally (4) (5) (6) (7). It may well be that form-coke may make initial inroads into the metallurgical field as a supplementary source of carbon.

With regard to the coal-industry, the source of supply of the traditional coking coals is changing. The premium coals of the Appalachian coal field are becoming scarce and more expensive to mine and the carbonization industry is now looking for alternate sources. Investigations are required to evaluate the coking properties of new coal seams for their commercial application in the established markets and their applications in new markets. To keep abreast of the current general technological changes, research studies are necessary to provide adequate apparati and methods of tests, designed to provide a better insight into the coal properties and their behaviour on thermal decomposition. Reduction in the sulphur and the mineral-matter-contents of coal to levels of the order of 0.7 and 5 per cent respectively is a prerequisite if the coals are to command a market in the integrated steel industry of the future. This requires increased activity in those studies related to coal preparation. Fine coal will be associated with this problem, necessitating coal agglomeration in many cases prior to its use. The effect of this type of coal beneficiation on the coking properties is important to the coke oven operator thus requiring studies of the carbonization behaviour in laboratory equipment and in pilot plant coke ovens prior to industrial application. New and improved methods of coal transportation are necessary to reduce the cost of the coal to the consumer and to bring into use coals previously uneconomic because of remote and inaccessible locations. Pipelining of solids in slurry form is currently being considered for many materials and may be applicable to coal (8) (9) (18) (19). Conditioning of the coal for this mode of transportation is presently unfamiliar to the industry. Research studies are necessary to provide means of carbonizing coal slurries for use in the existing standard slot-type coke ovens.

The aforementioned remarks pertain to some of the problems in the expanding coal and coke industries--that sector of the economy which the activity is intended to serve.

Carbonization projects have been carried out and projects are in progress to assist in many of these problems.

(3) Relation to Other Division Activities

The projects dealing with this sub-activity are in many cases related to other activities in the Metals Reduction and Energy Program. For example, the carbonization characteristics of coals or beneficiated coals are required for the other divisional activities dealing directly with coal preparation, pyrometallurgy, air and water pollution, and energy and coal transportation. The services of the laboratory and pilot plant are an integral part of the divisional activities.

(4) National Need

The coke industry of Canada is small in comparison with that of the United States, but it has progressed through the various phases of development experienced in other countries. Coke production in Canada approximates 5 million tons annually (1). Metallurgical coke requirements are increasing in quantity and quality with a decline in the availability of good coking coals from the traditional sources in the United States. The situation has resulted in increased demands for the technology of coal beneficiation and carbonization.

Since the termination of World War II, the coal industry of Canada has suffered a loss of its traditional markets due to competition from other fossil fuels. Recently, the industry in Western Canada has made a phenomenal comeback in the establishment of new markets for coking coals, particularly coal for exports to Japan. At the present time, 174 million tons are contracted for over the next 15 years. Exploration work is in progress in the Foothills belt of Alberta and British Columbia and it is likely that new seams will be uncovered for the export and the domestic markets. It appears that by 1975 the production of coking coal alone in the provinces of Alberta and British Columbia will exceed the all-time total peak production in Canada of 19 million tons established in 1950 (11)(12). The unavailability of coking coals in the United States indicates promising outlets for Canadian coals on this continent. (Europe and South America are also potential markets). Improved transportation techniques, such as the pipelining of coal slurries, may provide new markets previously out of economic range.

Carbonization and associated divisional projects have been active in assisting the coke-industry in the various problems associated with operations of commercial coke plants. Approximately 85 per cent of the coke production in Canada is manufactured by four Canadian integrated steel plants. The greater portion of the experimentation related to their coke-making problems is carried out under this activity through some financial assistance of the Canadian Carbonization Research Association (13).

The carbonization studies have been important in establishing the market for coal in Japan (14)(15)(16). Projects are in progress to assist the coal industry in exploration work and in maintaining quality control. Studies have also been carried out to assist the industry in the development of other markets (17).

The coke-industry in general is expanding with increased demands regarding coke quality. The coal industry of Western Canada is entering a period of movement of large tonnages of coal principally into the export market. The coke-industry of Eastern Canada is now operating at capacity and is contemplating further expansion. Continued and expanded research in the Metallurgical Fuel Activity is required to assist the coal and coke industry of Canada.

(5) Alternatives

Fuels research in Canada is also carried out by provincial government agencies in the provinces of Alberta and Nova Scotia, namely the Research Council of Alberta and the Nova Scotia Research Foundation respectively. Carbonization and related studies are included from time to time related to provincial problems in this area; studies are also undertaken of a fundamental nature in the long-term interests.

The Canadian coal research programs are reviewed annually by the Canadian Advisory Committee on Coal Research.

The carbonization and associated facilities of the Mines Branch are the only facilities available in Canada for a complete evaluation of carbonization problems prior to commercial oven trials. Alternative sources of similar facilities and carbonization "know-how" are available in part in the United States from certain coal suppliers, the U.S. Bureau of Mines, Bituminous Coal Research Incorporated, consulting firms and steel plants.

(6) Criteria

The coal industry is approaching an era of the highest production of coking coal in the history of Canada. To maintain its new-found markets and to establish other potential markets, research studies are urgently required.

The coke industry is faced with the use of new sources of coal with increased demands on coke quality. Technical-scale test programs with new coals are necessary prior to commercial application including research studies on methods of improving coke quality and coke oven throughput.

(7) Preferred Course of Action

It is generally recognized that for a reliable evaluation of the properties of coals or coal blends for use in standard slot-type coke ovens it is mandatory that tests be carried out at the technical-scale level.

The carbonization facilities at the Mines Branch are the only facilities available in Canada to carry out a complete investigation on carbonization problems.

In order to provide coal quality acceptable for the future markets in metallurgical processes, beneficiation studies are necessary to find economic means for reducing the mineral-matter and sulphur contents of certain Canadian coals.

Fine coal associated with beneficiation and coal transportation problems will necessitate agglomeration research.

It is recommended that the projects in progress under this subactivity be continued and expanded to fulfill the national requirements of the coal and coke industries.

(8) Project Titles and Technical Objectives

a) Research and Development in Coal Beneficiation, Conventional and Non-Conventional Coking Processes, and New Applications for Coal in Metallurgy

Research and development projects are carried out to assist the coal and coke industries with the following objectives in mind:

(1) To develop new test methods to provide a better insight into the coking mechanism.
(2) To utilize marginal coking coals and other sources of carbon not normally used in the industry.
(3) To increase the coke productivity and the efficiency of conventional coke plants.
(4) To develop new processes for coke-making.
(5) To study various beneficiation agglomeration and coal pretreatment techniques applicable to the metallurgical industry.

b) Industrial Investigations for the Coal and Coke Industries

Investigations are carried out to assist the Canadian coal and coke industries in confidential 'ad hoc' problems of specific interest.

Projects related to the evaluation of the coking properties of coals are carried out to assist the Canadian coal industry in the exploration, mining, preparation and utilization of coking coals.

c) Service

Advisory information and technical reports are supplied to other government agencies, industry and others as required.

Preparation of samples, analysis and bench-scale test data related to the use of fuels in metallurgy are provided as a service to other groups in the Department as required.

(9) Project Costs and Scheduling - Carbonization Research

This estimate includes:

1) Coal processing, coking processes, and new coal applications.
2) Industrial investigations for coal and coke industries.
3) Service.

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	9	9	9	15,000	405,000
Technicians	14	14	14	8,000	336,000
Overhead					111,000
Total					852,000

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APPENDIX 1

Research and Development in Coal Beneficiation, Conventional and Non-Conventional Processes, and New Applications for Coal in Metallurgy

(Example of Currently Active Studies - Carbonization Section only)

3-2-0/1-2	Development of Improved By-Product Recovery System for the BM/AGA Carbonization Apparatus.
3-2-0/1-4	Development of the 18 inch MW Coke Oven.
3-2-0/1-8	Development of the 30 lb Coke Oven.
3-2-0/1-12	Development of the Mines Branch 12 inch MW Coke Oven, MK II 1969.
3-2-0/3	Development Bench-Scale Equipment for the Rheological Properties of Coals (except Gieseler Plastometer).
3-2-0/10	Study of Transportation of Coals and Associated Products.
3-2-0/12	Studies of the Correlation of the Various Coal Parameters to the Coke Characteristics.
3-2-0/15-2	Development of a Fully-Automated Semi-Portable Type Plastometer.
3-2-0/15 (3 to 7)	ASTM Task Group Studies on the Gieseler Plastometer.
3-2-0/16	Technical-scale Coke Oven Studies on High Density Coal and Preheated Coal Charges.
3-2-0/18	Studies on the Application of High-Carbon Additives to Coke Oven Charges.
3-2-0/22	Study of the Characteristics of Coals of Varying Rank but of the Same Orogenesis.
3-2-0/19-4	Investigation of the Coking Properties of an Illinois Coal (Orient No. 3) in Relation to its Application as a Reference Marginal Coking Coal.
3-2-0/23	The Effects of Mineral-Matter in Coals on Carbonization Characteristics.
3-2-0/4	Non-Recovery Coke Oven Applications.
3-2-0/6	Study of Methods for Improving the Coking and Coking Properties of Weakly Coking Coals.

APPENDIX 2

Industrial Investigations for the Coal and Coke Industries

(Example of Currently Active Studies - Carbonization Section only)

3-2-1/2	Coals from the Mountain Park Area Alberta (Luscar Coals Ltd.).
3-2-1/3	Coals from the Upper Elk River Coal Area, B. C. (Fording Coal Co. Ltd.).
3-2-1/12	Coals from the Cascade Area, B. C. (Canmore Mines Ltd.).
3-2-1/16	Coals from the Crowsnest Area, B. C. (Kaiser Resources Ltd.).
3-2-1/18	Coals from the Telkwa Area, B. C.
3-2-0/8	Studies Related to Coke-Making at the Coke Plant of the Algoma Steel Corp. Ltd. , Sault Ste. Marie, Ontario.
3-2-0/9	Studies Related to Coke-Making at the Coke Plant of the Dominion Foundries and Steel Company Ltd. , Hamilton, Ontario.
3-2-0/14	Studies Related to Coke-Making at the Coke Plant of the Steel Company of Canada Ltd. , Hamilton, Ontario.
3-2-1/15-2	Study of the Coking Characteristics of Coals Stored at the Coke Plant of Devco, Sydney, N. S. (1966-1969).
3-2-1/15-5	Physical Testing of Commercial Coke Samples from the Devco Coke Plant, Sydney, N. S.
3-2-1/20	Coals from Smoky River Area, Alberta (McIntyre Porcupine Mines Ltd.).
3-2-1/10	Utilization of Western Canadian Coking Coals in the Integrated Steel Industry of Central Canada.
3-2-1/14	Western Canadian Coals for Export to Japan.

SUB-ACTIVITY 3: PYROMETALLURGY RESEARCH

The goals and objectives are:

- to develop the electric smelting process for the production of iron and other metals.
- to develop new processes for the treatment of sulphide ores.
- to recover marketable products from unusual ores or process by-product materials.
- to alleviate air pollution conditions arising from electric furnace operations.
- to study the agglomeration of ores and concentrates.
- to provide a consultative service to the Canadian pyrometallurgical industry.

(1) Situation

The objective of the Pyrometallurgy sub-activity is to seek ways and means of improving the efficiency and lowering the cost of pyrometallurgical processes used for treating Canadian ores and to explore the possible economic benefits of applying metallurgical techniques to ores and related materials which have not been treated by such processes. In many cases the pyrometallurgical approach is the only practical economic route for producing metals, alloys, etc. from these non-renewable resources.

Pyrometallurgical processes are characterized by relatively high energy requirements and consequently the cost of the energy often represents a substantial portion of the cost of the process. Some conventional pyrometallurgical processes such as blast furnace pig-iron production must be carried out on a very large scale to remain economically competitive and this requirement does not always fit well with Canada's thinly-dispersed population. Hence, powerful incentives exist to develop processes which will utilize the cheapest available sources of energy in the most efficient manner and for processes that would be economically viable on a modest scale. In addition, many pyrometallurgical processes have in past years been important contributors to air and water pollution and there is urgent need for improvements and modifications to eliminate these problems.

A combined shaft-electric furnace has been under development in this Group for about 6 years. It has been demonstrated (1, 2, 3) that the unit can be used for the treatment of oxide ores and for the melting of prereduced iron pellets. In both of these applications, much of the electrical energy required in conventional electric furnace practice can be replaced by energy derived either from a cheaper fossil fuel or from improved utilization of the energy contained in the off-gases. Two campaigns were carried out in the pilot-plant during the summer of 1969 and extensive use was made of computer technology both to provide assistance in controlling the operations and to aid in the subsequent analyses and study of the data.

In the development of this shaft-electric furnace only limited attention has been given to date to the air pollution aspects, although some studies have been made of the dusts and fumes evolved when these caused operating difficulties.

Although the shaft-electric furnace development has occupied much of the time and effort of the Group for the past five or six years, other projects also have received attention (4). Because sulphide ores constitute such an important segment of Canada's mineral resources, some background studies have been made and some exploratory experimental work has been done regarding processing methods for these ores. Also some preliminary studies and exploratory experimental work have been done with a view to finding methods for economically recovering metals or compounds from low-grade ores or waste process materials.

(2) Planning Assumptions

(a) The primary goal that was established when the combined shaft-electric furnace development work was begun about six years ago, namely the development of a unit that would be well-suited for the smelting of oxide ores, has been largely achieved. Much of the progress made in applying the unit for smelting oxides ores and for melting prereduced iron pellets has already been reported (2, 3); reports on the two most recent campaigns are in preparation. Although there are a number of areas where further improvements could be made, we believe that specific applications in industry should be studied before making decisions regarding the specific directions for further pilot-plant work on this project.

(b) No further operation of the pilot-plant is planned for the coming year, in fact none can be planned until additional staff is obtained and trained.

(c) While awaiting industrial studies regarding the shaft-electric furnace development, some effort will be devoted to exploring and evaluating the benefits derived from the computer assistance in the recent pilot-plant operations. Also, attention will be shifted to other problems which we regard as important, but which we have not been able to devote much time to in the past five or six years (See Section (8), Project Titles and Technical Objectives).

(d) Increased attention will be devoted to air and water pollution problems associated with pyrometallurgical processes.

(3) Relation to Other Mines Branch Studies

The preferred courses of action of the Pyrometallurgy sub-activity, which are outlined later under Item (7), are related to other Mines Branch studies as follows:

a) Improvement of Electric Furnace Efficiency

The shaft portion of the combined shaft-electric furnace acts as a fairly effective filter for much of the dust and fume produced in the electric furnace portion, and tends to make the subsequent cleaning of the gases easier. As was noted earlier, some limited attention has been given to the fume and dust evolved in this operation, and it is intended that increased attention will be devoted to this in the future. This is related to some other studies currently underway in other divisions on particular air-borne contaminants, as reported under the Air Pollution Abatement and Air Resource Management Program in the memorandum "Program and Project Priorities - Program Statements" by F. T. Rabbitts, August 22, 1969.

b) Development of New Processes for Treating Sulphide Ores

The importance of sulphide ores in the Canadian mineral resource picture has long been recognized. The Mineral Sciences Division has for several years been pursuing a program devoted to acquiring new information about sulphide minerals. The problem of SO_2 emissions from ore smelters is closely related to the similar problem in fuel-fired power-generating and heating plants, which is also listed in the Air Pollution Abatement and Air Resource Management Program. In the early part of 1969, a new method of treating certain sulphide minerals was proposed by the Research Section of the Extraction Metallurgy Division and consideration was being given by both the Hydrometallurgy and Pyrometallurgy Sections to further investigation into the process, because it involved both hydrometallurgical and pyrometallurgical steps. It is proposed that this joint effort should continue.

c) Recovery of Marketable Products from Unusual Ores and Process Waste Materials

A limited amount of investigation has been done into the possibility of recovering vanadium oxide and nickel from the ash residue from the processing of Athabasca tar sands. The Fuels Division has of course been vitally concerned for many years with the problem of utilizing these tar sand resources.

Another problem that has received some attention is the recovery of the nickel and chromium contained in asbestos tailings: this problem also has received some attention in the Mineral Processing Division (5).

(4) National Need

A process which would economically produce pig iron on a modest scale and which would utilize local resources of materials, energy, etc. would be of great benefit in several parts of Canada. Also, because the electric furnace is well suited for steelmaking on a modest scale, any improvement to conventional practice which would permit an appreciable fraction of the electric energy to be replaced by a cheaper fossil fuel would be advantageous.

There is little doubt that pollution of the environment is one of the gravest problems facing the country. In the past, pyrometallurgical industries have been heavy contributors, particularly to air pollution. Pollution abatement measures would be more readily adopted by industry if they could be coupled with process modifications which would result in recovery of valuable by-products, improvements in efficiency, etc.

(5) Alternatives

(a) As this is the only general purpose technical-scale pyrometallurgy laboratory in Canada the alternatives are:

(i) either no work of kind in Canada, or
(ii) some method of encouraging Canadian industry to do this work.

(b) For some metallurgical processes hydrometallurgical options are available but not so for the bulk of iron production and certain other metals. Pyrometallurgical studies will thus remain essential to the maintenance of this large Canadian industry.

(c) Only certain processes can be chosen for study at an industrially interesting scale due to a very small staff and budget. Since electricity is relatively cheap and with the electric furnace facilities available, it seemed sensible to concentrate on this particular approach, especially considering the large Canadian electro-thermic industry.

(6) Criteria

The criteria used in selecting projects for future attention were:

(a) National Need

Projects were selected which we believe will best serve the national needs outlined earlier. This means that efforts will be devoted to the development of processes that will be best suited for Canadian conditions and which will aid in the economic development of those areas that need it most. Only minor improvements are needed to make a significant economic contribution.

(b) Pollution Abatement

There will be a strong emphasis on pollution abatement aspects because of the urgency of this problem.

(7) Preferred Courses of Action

(a) Improvement of electric furnace efficiency by means of the newly-developed shaft-electric method, particularly as applied to iron ores and prereduced pellets embracing full marginal improvements to existing processes and to develop an entirely new preheating and prereduction approach.

(b) Smelting of sulphide ores in the shaft-electric furnace in such a way as to minimize SO_2 emission. (Cooperative with other studies). Control of SO_2 for sulphide processes is now the most important general problem confronting this important branch of our mineral industry.

(c) Recovery of marketable products from off-grade or unusual ores and concentrates, particularly as applied to the ferro-alloy industry.

As time permits other projects will be undertaken within the broad fields as follows:

(i) Fundamental studies of slag systems and their influence on electric arc furnace operating characteristics.
(ii) Electrolytic processes in extractive pyrometallurgy.
(iii) Fundamental studies on reduction mechanisms, reaction kinetics, etc.
(iv) High vacuum technology in extractive pyrometallurgy.
(v) Plasma arc technology in extractive pyrometallurgy.

(8) Project Titles and Technical Objectives

a) Improvement of Electric Furnace Efficiency

Electric furnaces are widely used for smelting oxide ores to produce metals, ferro-alloys, refractory materials, etc. They are assuming an increasingly important role in steelmaking and they also are used in certain places for pyrometallurgical treatment of sulphide ores. The project that has been underway in our laboratories has several objectives:

(i) To develop a combined shaft-electric furnace, which would be more efficient than conventional electric furnaces, for the melting or smelting of oxide ores to produce marketable products such as pig iron, fused refractories, etc., to provide the first usable pre-reduction and preheating system applicable to the electric smelting process.

(ii) To investigate the suitability of the combined shaft-electric furnace for melting prereduced iron pellets to produce steel to take maximum advantage of extensive Canadian development of new types of reduction processes.

(iii) To investigate the feasibility of producing steel, on a continuous or near-continuous basis by treating iron oxide pellets in the unit. The combined shaft-electric furnace offers this still not industrially realized objective.

(iv) To investigate the feasibility of using the combined shaft-electric furnace for treating sulphide ores, i.e., matte-smelting operations.

(v) To pursue studies aimed at alleviating the air pollution problems associated with electric furnace operations.

b) Development of New Processes for Treating Sulphide Ores

The objective of this project is to explore the possibility of developing new methods of treating sulphide ores which would alleviate the air pollution problems associated with current pyrometallurgical methods. Particular attention will be given to methods that would result in the recovery of sulphur in its elemental form. It is possible that some of these processes might involve both hydrometallurgical and pyrometallurgical steps. This investigation will be integrated with other Mines Branch programs.

c) Recovery of Marketable Products from Unusual Ores and Process Waste Materials

The objective of this program is to develop methods of recovering metals and other compounds of value from low-grade or unusual ores, or from process waste materials. Examples might be the recovery of nickel and vanadium from tar sand residues, manganese from low-grade ores, nickel and chromium from asbestos tailings, etc.

(9) Projected Costs and Scheduling - Pyrometallurgy Research

The following estimate includes:

1) Improvement of Electric Furnace Efficiency.
2) New Processes for Sulphide Ores.
3) Marketable Products from Unusual Ores and Waste Materials.

	Man Years per Year			Cost per	Total Cost
	72/73	73/74	74/75	Man Year	for 3 Years
Professionals	4	4	4	15,000	180,000
Technicians	5	5	5	8,000	120,000
Overhead					215,000
Total					515,000

(10) Benefits

(a) Improvement of Electric Smelting Efficiency

The two most important benefits from this project will be: (1) the development of a smelting and melting unit of high efficiency which can be installed in small units and thus will suit many areas in Canada where the population density is low and (2) the development of a unit which by its very operating principle does some preliminary filtering of its waste gases and completely burns and cools these gases within itself. These features should make subsequent gas cleaning for anti-pollution purposes much cheaper.

This project has been in progress about six years. During this period both iron oxide pellets and prereduced iron pellets have been used as feed material. For example, in the case where iron oxide pellets were smelted to produce pig iron, a saving of about $6.00 per ton of pig iron is indicated by the results of a recent pilot plant experiment in which about 100 tons of oxide pellets were treated. This estimate was made by comparing the experimental energy consumption figures with published data from conventional electric smelters (6, 7, 8). In the case where prereduced iron pellets were melted, the results of pilot-plant operations in which about 200 tons of pellets were treated indicate that a saving of about $1.00 per ton of product is possible when compared to melting pellets of this type in conventional electric furnaces.

b) Development of New Processes for Treating Sulphide Ores

The major benefit of this project would be the development of new processes for treating sulphide ores which would minimize or perhaps eliminate the serious air pollution problems of the methods currently in use. Calculations based on published data (9) indicate that in Canada there are at least 500,000 tons of sulphur vented to the atmosphere in the form of sulphur dioxide each year, due to the processing of sulphide minerals. While it is true that if this material could be recovered as elemental sulphur it would have a value of about $15 million annually, the major benefit consists in allowing an important segment of the Canadian economy to continue to expand.

c) Recovery of Marketable Products from Unusual Ores and Process Waste Materials

Some of the unusual ores and process waste materials that have already received attention are located in areas where the establishment of new industries would be of great benefit to the local economy. Examples are low-grade manganese ores in Saskatchewan and in the Maritimes, asbestos tailings in Quebec, and tar sands residues in Alberta. For example, it is estimated that at current prices the nickel contained in the asbestos tailings piles is worth more than $1 billion, while the nickel and vanadium contained in the tar sands are each worth about $50 million, so obviously any process developed to treat these materials will result in large benefits. With a successful process the cost/benefit ratio could easily exceed 10:1.

(11) Input and Output Estimates

a) Improvement of Electric Furnace Efficiency

The development of this shaft-electric furnace has been in progress for about six years and has cost about $600,000 to date. It is estimated that the additional input for the next five years will be about $350,000. Although this development project has five technical objectives, which were outlined earlier, to date substantial progress has been made on only the first two of these, i.e., the smelting of iron oxide pellets to produce pig iron and the melting of prereduced iron pellets. It is possible, at the present time, to get a reasonably clear view of the potential benefits in these two applications. In the case of pig iron production, published figures (10) show that about 100,000 tons of pig iron were produced in conventional electric furnaces in Canada in 1968. Assuming that these conventional electric furnaces were converted to shaft-electric furnaces, the indicated saving of $6.00 per ton would mean a benefit of about $600,000 per year, or $6 million over a 10 year period. In the second application, i.e., the melting of prereduced iron pellets, the experimental results indicate a saving of about $1.00 per ton over conventional practice. Published data (10) show that about 1.5 million tons of steel were produced in electric furnaces in Canada in 1968. Most of this was produced from iron and steel scrap, and it would not be realistic to expect a sudden shift from this practice to adopt the shaft-electric furnace approach using prereduced iron pellets, especially since prereduced pellets are not yet being produced on a large scale in this country. In fact, the commercial production of prereduced pellets will depend mainly on the success that The Steel Company of Canada, Esso Research Ltd., and others have in establishing commercial operations using their respective reduction processes. However, if it is assumed that prereduced pellets will become available and if they were to account for a reasonable proportion, say one-third, of the electric furnace steel production, this would mean that about 500, 000 tons of steel could be produced via this route with a saving of $500, 000 per annum or $5 million over a ten year period. Thus the total benefit for these two applications could reach $11 million and, using an input figure of $950,000, the benefit to cost ratio would be about 12:1.

If success is achieved in pursuing the other technical objectives of this project, additional benefits could occur, which would of course increase the above indicated benefit to cost ratio.

b) Development of New Processes for Treating Sulphide Ores

As indicated earlier the potential benefit from this project could reach $15 million annually or about $150 million over a ten year period. It is estimated that the input to this project to the end of the fiscal year 1974 will be about $225, 000. The major reason for the project is, however, to develop an acceptable process from the pollution standpoint which will allow growth in this very important segment of the mineral industry.

c) Recovery of Marketable Products from Unusual Ores and Process Materials

The value of the nickel, vanadium, etc., in the two cases described earlier is very great--in excess of $1 billion. It is estimated that the input to the project to the end of fiscal year 1974 will be about $210, 000. These figures suggest a very high benefit to cost ratio if success were achieved--a figure high enough to justify the effort.

(12) References

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SUB-ACTIVITY 4: SPECIAL RESEARCH

The goals and objectives are:

- to assess the energy needs of the Canadian metals and minerals industry.
- to carry out programs aimed at new outlets for Canadian fuels in the metals and minerals industry, the alleviation of problems concerning energy supply, the study of the transport of energy and the study of energy using processes in the metals reduction field aimed at both energy economy and the development of new up-graded metallurgical products from concentrates.
- to apply the results of these studies to the Canadian economy by organizing industry-government groupings.
- to program and administer the sub-activities to obtain required results.

Project 1 - Research in Coal Fines Processing

(1) Situation

The future utilization of Canadian coking coal will probably require processing much higher proportions of finer-than-normal coal sizes as will be seen below. The principal Canadian steel plants, because they are widely separated from the coking coals of Alberta and Cape Breton, import all their coking coal (~6, 000, 000 t/p/y) from the U. S. Even the steel mill at Sydney, N. S. presently imports 30% of its coking coal. Because of the growing competition for dwindling supplies of U. S. low-sulphur coals, it is likely that serious attention must be paid to the utilization of Canadian coking coals.

Cape Breton can provide good coking coal, but it is expensive and high (1-2%) in sulphur. However, about 60% of this sulphur can be removed by processing the coal in finer sizes (1/8" x 0 to 28 x 0) and, if the lower sulphur coal is selected, a satisfactory supply of coking coal for local needs will be available.

If Western Canadian coal is to be used by Central Canada steel mills, it could be transported by pipeline. Although Western coal is low in sulphur (~0. 4%) and does not require fine grinding for beneficiation, pipeline transport requires a relatively high proportion (~20%) of -325 mesh fines in a consistency of 1/8" x 0. Moreover new mechanical methods of mining now coming into general use produce a higher-than-normal proportion of fines and utilization of these sizes is important for economic and technical reasons.

At present coking plants use 1/8 x 0 in. coal dried to at least 8 per cent moisture. The finer (28 x 0) portion of coal, if beneficiated at all, is processed by flotation, dewatered on vacuum filters and dried in fluid-bed thermal driers. Flotation is not efficient at the smaller sizes (100 x 0) of coal and drying fine coal is expensive; in addition, it contributes seriously to atmosphere pollution and can adversely affect by oxidation the coking properties of the fine coal. It is evident that existing methods of coal beneficiation and drying are not readily adaptable to the finer coal sizes.

(2) Planning Assumptions

Canadian steel mills will have increasing difficulty in obtaining additional supplies of coal in the foreseeable future and will make use of Western coking coals. A substantial proportion of future coking coals may consist of finer (1/8" x 0) sizes comprising at least 20% 125 x 0m.

Fine-coal beneficiation will require marked improvement to take full advantage of Canadian coals. Dewatering must be achieved by cheaper and cleaner methods and provide protection against oxidation of finer fractions. Fine coal will require agglomeration to conventional coke-oven charging size (80% 1/8" x 0) for at least part of the future coke production. Form coking (from briquettes and pellets) will become common and will also use coal in fine sizes.

(3) Relation to Other Mines Branch Studies

The addition of hydrocarbons to water slurries of fine coal for the purpose of agglomeration, but more particularly as a means of rejecting mineral matter, is related to flotation and other surface-reactive processes which are the subject of research and development by the Mineral Processing and Mineral Sciences Divisions.

(4) National Need

Importation of U.S. coals constitutes an undesirable dependence upon sources beyond Canadian control. It also contributes considerably to foreign exchange imbalance. There is a growing need to make Canadian coking coals available to Central Canada steel mills.

The possibility of pipeline transport of Western coal to the West Coast for shipment to Japan demands a knowledge of the best methods of dewatering and agglomerating coal of pipeline consist.

(5) Alternatives

To await clearer indications of the direction of industrial and national needs and the resolution of related problems by other research organizations or private companies. This would deprive the Mines Branch and the Department of a background of knowledge and experience upon which to judge the importance of problems and the feasibility of suggested courses of counter action; it would also reduce the possibility of the Department's direct contribution to the solution of specific industrial problems.

(6) Criteria

The objective of Project 1 is to identify the most likely technical and economic processes for using Canadian coal fines for coke production, consistent with the predicted restrictions of pollutants to soil, stream and air. The technical and economic position of present processes would form the basis of feasibility criteria. It is to be expected that costs will be higher than for conventional processes but a principal objective will be that the benefits would substantially off-set higher costs.

(7) Preferred Courses of Action

To make critical assessment of the technical and economic feasibility of relevant processes report in the literature and otherwise; to make exploratory experiments into novel approaches to dewatering, agglomeration and beneficiation of Canadian coal fines; to characterize experimentally the properties of fine coal agglomerates with respect to dewatering and the water resistance, mechanical strength and oxidation resistance of dried agglomerates.

(8) Project Titles and Technical Objectives

1) Agglomeration of Coal Fines in Water Suspensions by Oil and Tar Additions

Objective: to determine the best methods of agglomeration consistent with desired agglomerate size (1/8" x 0), low hydrocarbon consumption, low energy input, short residence time and low residual water content.

2) Low-Temperature Thermal Drying of Tar-Agglomerated Coal Fines

Objective: to determine the best industrial approaches to low temperature ($<100°C$) drying of tar-agglomerated coal fines.

3) Centrifugal Dewatering and Agglomeration of Coal Fines

Objective: to determine whether agglomerate density can be increased, hydrocarbon consumption and residual water content be reduced by the application of centrifugal force.

4) Beneficiation of Coal Fines in Water Suspension by Oil-Agglomeration in the Presence of Dispersed Air

Objective: to explore alternative methods to oil flotation by novel use of equipment.

5) Characterization of Oil-and-Tar-Wetted Coal Fines in Thermal Drying Processes

Objective: to indicate quantitatively the enhanced drying characteristics of oiled coal in contrast to unoiled coal.

6) Characterization of Water-Proof Properties of Tar-Wetted Coal Fines Agglomerates

Objective: to determine the degree of waterproofing imparted to coal by tar agglomeration.

7) Characterization of Oxidation Resistance of Tar-Agglomerated Coal

Objective: to determine the degree of oxidation resistance imparted to coal by coal-tar agglomeration.

(9) Projected Costs and Scheduling

(See page 235).

(10) Benefits

Development of processes for desulphurizing Cape Breton coal and coke would result in utilization of local coals. This would result in saving the foreign exchange for the corresponding amount of U. S. coal and in saving subvention payments to move the coal (aside from that used for coking at Sydney) to Ontario power plants. Furthermore, Cape Breton might well develop a significant overseas market for coke as evidenced by recent small shipments to Europe this year.

Movement of Canadian Western coal to Central Canada could provide a large low-sulphur coal source to U. S. steel mills.

Project 2 - Research in the Application of Coal, Coke and Associated Products to Industrial Processes

(1) Situation

Many Canadian ores although abundant are frequently low-grade; consequently, extraction-processes must either use cheap non-recoverable reagents or be reagent-recovery processes.

Lignite, coal and coke are amongst the cheapest chemical reagents costing as little as 0. 2 to 1. 0 cent per lb. Coke is not only a powerful reducing agent for the treatment of oxide minerals and products, but because of its high porosity, low density and physical strength makes a desirable material in adsorption processes involving gases and liquids. It is also a potential extender in Portland cement and in plastics.

Pyrite, a by-product of the coal industry in Nova Scotia and New Brunswick, could provide a source of reductant (sulphur) as well as a potential supplementary source of iron.

(2) Planning Assumptions

Traditional extraction processes, particularly for treating sulphide concentrates, will be markedly modified and greater use will be made of reductive processes either alone or in combination with other processes to alleviate atmospheric pollution by SO_2.

Direct reduction of iron ores and of iron components in mixed oxide-type ores such as ilmenite and chromite using coal products as reductants will become more common in the next five years.

Chlorination of low-grade ores will gain prominence because of its versatility in treating both oxide- and sulphide-type ores and metallurgical materials and because of its adaptability to a wide variety of reaction conditions from very low to very high temperatures (depending upon the materials treated) and because of its adaptability to a wide variety of product-separation and purification procedures.

(3) Relation to Other Mines Branch Studies

The Mineral Sciences Division, which is engaged in basic research on oxide and on sulphide systems, is a source of thermodynamic information upon which the Metals Reduction and Energy Centre can draw in its investigation and development of metallurgical processes. The Extraction Metallurgy Division is a source of both thermodynamic and kinetic data on oxide and sulphide systems.

(4) National Need

Considerable need exists to exploit low-grade Canadian ilmenite deposits since the expanding titanium pigment industry is turning more and more to chlorination to achieve a superior pigment and to avoid the problems of iron sulphate disposal. Canadian production of artificial rutile by way of ilmenite would provide raw material for both pigment and the iron industry and a potential export of rutile at a value of about $100 per ton in an industry that consumes many thousands of tons per year of ilmenite.

Treatment of sulphide-ores by alternative methods to smelting and economic recovery of SO_2 from smelter gases are greatly needed for new plants in the immediate future.

Markets for Maritime coal and coke are needed to stimulate industries in those provinces.

(5) Alternatives

To ignore within the Centre all but the steel industry in the utilization of coal and coke products. This could result in some loss of exploitation of coal resources since some processes and uses of these products would be less obvious to those less acquainted with the versatility of coal.

(6) Criteria

The identification of feasible processes related to Canadian minerals which would use Canadian coal, coke or related products for the production of exploitable products of significant value.

(7) Preferred Courses of Action

To investigate by literature surveys and exploratory laboratory experiments and by consultation with officials in the mineral industry possible adaptations of proven processes to specific Canadian problems and the development of novel approaches for the production of new products and new markets using products of the coal industry.

(8) Project Titles and Technical Objectives

1) The Adsorption of SO_2 on Activated Cokes and Chars

Objective: to provide insights into the required properties for SO_2 scrubbers in smelting and electric power station stacks.

2) The Investigation of Low Temperature Chlorination of Oxide Ores

Objective: to reduce chlorinating temperatures to 500°C or less.

3) Preferential Reduction of Iron Components in Ilmenite by Coal and Coke Products

Objective: to improve extent and rate of reduction of iron oxides in ilmenite ores.

4) The Reduction of Pyrite by Millscale

Objective: the development of a low-temperature, low-cost process for the complete recovery of elemental sulphur from pyrite.

5) The Reduction of Pyrite by Millscale

Objective: the recovery of low grade iron (unusable for blast furnace scrap) for conversion of pyrite to pyrrhotite.

(9) Projected Costs and Scheduling

(See page 235).

(10) Benefits

The development of expanded markets for coal and coke in Canada and abroad for metallurgical processes. Assistance to the mineral industry in exploiting low-grade Canadian oxide and sulphide mineral deposits.

Project 3 - Research on Special Control Analytical Methods

(1) Situation

Because of the nature of this activity there is a need for the development of simple rapid control analytical procedures applicable to coal and to metallurgical reduction processes. There is also a need to provide procedures to characterize the physical and chemical properties of the products of coal processing research and of the products of the Centre's experimental coke ovens.

(2) Planning Assumptions

It is assumed that the demand within the Centre for simple rapid control analyses of coal and metallurgical products will expand as the Centre's involvement in industrial problems expand and that the Centre will have to develop its own methods of control analyses to provide on-the-spot information in its development programs.

(3) Relation to Other Mines Branch Studies

Whereas analytical facilities are available in other Mines Branch Divisions and Centres (chiefly Fuels Research Centre and Mineral Sciences Division), these laboratories are concerned primarily with a degree of accuracy which is often unnecessary for exploratory work. Moreover, the service is one which must be shared with many other programs.

(4) National Need

This Project is part of an over-all program whose relation to the national need has been discussed above. In addition, it is intended to contribute as well to the reduction of pollution by the coal and coking industry products.

(5) Alternatives

Submission of control samples to regular analytical laboratories such as the Fuels Research Centre analytical laboratories. This would add unnecessarily to their work load and would tend to interrupt the flow of results from operating processes.

(6) Criteria

Control analytical procedures would be required to be simple enough to be used by non-analyst technicians, rapid enough to provide results within hours of sampling, and reliable enough to provide sufficiently precise indications (± 10%) of experimental results.

Procedures and equipment would be required to characterize the physical and chemical properties of a wide variety of products and to be capable of providing significant information with minimum complication.

(7) Preferred Course of Action

To conduct a program of development into sample control analytical procedures for coal and metallurgical products. To set-up versatile apparatus such as DTA, TGA and gas and liquid adsorption apparatus, adapted to relatively large samples to provide a wide choice of procedures to characterize the physical and chemical properties of different coal and metallurgical products and to determine the rates and character of relevant physical and chemical transformations.

(8) Project Titles and Technical Objectives

1) The Analysis of Total Sulphur in Coals by an Oxygen-Flash Procedure Using Arsenazo III as Titration Indicator

Objective: to provide a general and simple method for total sulphur analysis of coals.

2) Adaptation of the Eschka Method of Sulphur Analysis to a Volumetric Procedure

Objective: to provide a simple and quick volumetric alternative to the gravimetric finish of the Eschka procedure.

3) Improvement of Analysis for Oil and Water Content in Tar-Wetted Coal

Objective: to substantially reduce the time and to increase the accuracy of these analyses.

4) Adaptation of the Fluid Bed Technique for Enthalpy-Indicating Reactions

Objective: to provide a sensitive tool to measure physical and chemical transformation in relatively large (0.1 to 1.0 g) samples.

5) Apparatus for Controlling the Rate of Oxygen-Controlled Highly-Exothermic Reactions

Objective: to study exothermic reactions such as high-temperature oxidation of coals under close temperature control.

6) The Extraction of Water-Soluble Aromatic Compounds from Coke-Oven Effluent Water

Objective: to determine economically-feasible methods of reducing phenol-type stream pollution.

(9) Projected Costs and Scheduling

(See page 235).

(10) Benefits

1) The provision of control analytical methods to the low-budget coal laboratories and for field work.

2) To ensure closer control of experimental development programs within the Centre both in coal and metallurgical research.

3) To provide first-hand experiences with the problems of coke-oven products in soil, water and atmosphere pollution.

Project 4 - Research on Various Economic and Scientific Aspects of the Utilization of Fuels (mainly coal) as Sources of Energy or as Reducing Agents in Metallurgy

The main Sub-Projects are the following:

1) Research on the potential of Western Canadian coals as sources of energy in Central Canada and the Pacific Coast.

2) Research on the utilization of Western Canadian coking coal production by-products, such as coal middlings or oxidized coal.

3) Research on improvements of energy transportation methods, on both short and long distances, such as train-conveyors, improved integral trains, solids pipelines, EHV lines.

4) Research on fuels and energy storage methods, including natural gas, oil and coal storage.

5) Research on improvements in the utilization of energy and natural resources in fuel processing (including coal preparation, carbonization, coking), in fuel transportation and in the use of fuels and energy in metallurgy, and of fuels alone in power production.

(1) Situation

Sub-Project 1

Of the 15 to 20 million tons of U. S. coal imported each year into Ontario, about 5 million tons are used in thermal electric power plants and about 7 million tons are used in coking plants. In both cases there are possibilities for cheap large scale transportation of Western Canadian coals to replace some of the present consumption or; future growth of U. S. coal imports.

Sub-Project 2

The coking coal industry of Western Canada will soon produce 5 million tons of coal per year, rapidly increasing to 15 and perhaps 20 to 30 million tons of coal per year within a decade. A by-product of this industry will be middlings from the coal preparation plants and insufficiently coking coal which must be mined but cannot be sold for coking, e. g., oxidized coal.

Sub-Project 3

Fuel and energy transportation distances are so long in Canada that transportation costs are a very high proportion of delivered costs, often 50 per cent. Therefore any improvement in transportation methods is especially advantageous for Canadians.

Sub-Project 4

From a national welfare viewpoint as well as for the efficiency of operations, fuels and energy storage are important factors, although frequently neglected because the benefits are not immediate whereas the costs of storage are.

Sub-Project 5

Much of the fuels and energy are wasted during their utilization and there is much to be gained in the optimization of their utilization on the basis of their local costs and availability in each case.

(2) Planning Assumptions

Sub-Project 1

The best possibilities seem to be the following at present: 1 or 2 million tons of Prairie strip coal or processed lignite, or bituminous non-coking by-product coal to be transported on a continuous basis to one of the power plants of Ontario.

Sub-Project 2

It is assumed that 1. 5 and 0. 5 million tons respectively of middlings (of about 10, 000 Btu/lb) and of oxidized coal (of about 14, 000 Btu/lb) will be available next year in the Crows Nest Pass area, gradually increasing every year after with the growth of the coal industry in Western Canada. This fuel may be used in a common thermal plant close to the mines or shipped away, probably to the North West U. S.

Sub-Project 3

It is assumed that large quantities of fuels may have to be moved from one single area to another in the following minimum conditions: 1 million tons of coal on 200 to 2000 miles; 1 million tons of sulphur on 1000 to 2000 miles; 1 million tons of potash on 1500 miles; 1 million tons of iron, etc. on 1000 miles.

Sub-Project 4

Assumptions for storage requirements depends to a large extent on the particular circumstances of each case and may vary from 1 to 10 per cent or more of the annual consumption, depending on alternate sources of supply, local conditions, etc.

(3) Relation to Other Studies in Mines Branch and Elsewhere

This activity partly depends on studies in coal reserves, mining production, coal preparation and carbonization, coal transportation and statistics from the Dominion Coal Board, the Dominion Bureau of Statistics, the National Energy Board, the Geological Survey of Canada, the Mineral Resources Branch and generally speaking all research work active in similar fields.

(4) National Need

It is obvious, considering Canada's deficient balance of payments and the relatively low utilization of our coal resources and railway lines. About 0.5 million kw additional power plant capacity seems to be soon needed in South West Alberta or South East British Columbia.

(5) Alternatives

This activity could be contracted to private consultants or provincial government research organizations.

(6) Criteria

A Federal Government organization such as this Department seems to be the best group to undertake such a study.

(7) Preferred Courses of Action

To undertake our own research studies, but in good liaison with the other groups that may be concerned.

(8) Some Project Titles are Listed Below

a) Feasibility of common thermal power plants using coal middlings or oxidized coals from various mines in the Crows Nest Pass area or other similar areas.
b) Comparison of train-conveyors with solids pipelines.
c) Potential of coals and lignites from Western Canada as sources of energy for ontario.
d) Trends in per capita consumption of energy in Canada.

e) Background paper (for the June 1970 North American Fuels Conference) on recent data covering the consumption of various forms of energy, a survey of coal reserves and non-fuel uses of fuels, in Canada.

f) Comparison of the main systems of transportation of bulk solids.

g) Consumption of energy and fuels in the various mineral and chemical industries.

(9) Project Costs and Scheduling

This summary estimate includes Special Projects 1, 2, 3 and 4.

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	4	5	5	15,000	165,000
Technicians	2	3	3	8,000	64,000
Overhead					246,000
Total					475,000

C - EXTRACTION METALLURGY DIVISION

SUB-ACTIVITY 1: PYROMETALLURGY RESEARCH ANALYSIS

(1) Situation

Until recently the metal reduction projects were the responsibility of the Extraction Metallurgy Division. Now the group which conducted the process development studies in the field are part of the Metals Reduction and Energy Centre. It was agreed that some of the development of analytical methods and some support services would be supplied by the EMD to the new MR & E Centre because of the experience that EMD staff had with the metals reduction work when it was part of the EMD program.

(2) Planning Assumption

It will be necessary for the forecast period to continue to supply analytical and other assistance to the MR & E Centre.

(3) Relation to Other Mines Branch Activities

The work is integrated with the EMD analytical development program as well as other EMD support services and is a small fraction of the total EMD effort.

(4) National Need

It is assumed that the process development work done in the MR & E Centre and which generates the need for analytical development and other assistance has been shown to serve a national need.

(5) Alternatives, Criteria and Preferred Course of Action

As in (4) above, these considerations are relevant to the MR & E projects.

(6) Project Titles and Technical Objectives

a) Minimizing Energy Use in Metallurgical Processes

EMD projects in this area are mainly concerned with developing new methods for analysing the slags, matter, and alloys produced by the metal reduction processes which are under study. More accurate and faster methods are necessary to better understand the effects of process variables and conditions.

(7) Projected Costs and Scheduling

Minimizing Energy Use in Metallurgical Processes

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	0.5	0.5	0.5	15,000	22,500
Technicians	0.35	0.35	0.35	8,000	8,400
					30,900
Plant, service and overhead					30,600
					61,500

(8) Benefits

As with sections (4) and (5) above the benefits must be related to the MR & E work.

(9) References

Results of this project have not been reported as yet.

SUB-ACTIVITY 2: RADIOACTIVE MINERAL RESOURCES

(1) Situation

The Canadian uranium mining industry currently faces a very difficult position in marketing uranium concentrates, and it is forecast that this situation will likely continue until after 1975 (7). Because demand and prices for uranium are low, profit margins are low. This in turn is forcing the industry to limit its expenses in all fields including that of process research and development and, at present, most of the industry's R & D effort is directed towards solving environmental and mining problems with only a very little going into process development (11).

It is true that the effort that has gone into studies aimed at the development of processes for treating Canada's radioactive ores over the past twenty years has resulted in the development of a wide variety of processes suitable for treating our known ore reserves. The extent to which these developed processing concepts will be applicable will depend on how successful the industry will be in optimizing and integrating the whole operation right from development through mining and ore treatment to marketing (8). It is doubtful if sufficient attention is being given at the present time to this aspect of uranium production.

There are two points that do not strictly belong in this presentation, perhaps, but which should be mentioned because of their indirect bearing on the industry. First, it is clear that pollution control measures will be part of the cost of all mining and metallurgical operations in Canada. Therefore, all plant expansions and new plants, along with current plants for the uranium industry, will have to be operated in future in accordance with pollution control regulations. This presents an additional challenge to Canadian operators. Second, the recovery of rare earths and thorium would increase the returns from uranium operations and therefore the value of the operations to Canada. Therefore, the technology of by-product recovery, even though of minimal current interest, should be kept up-to-date against the time of industry expansion. These topics are considered to be part of the Environmental and Minerals and Metals Technology Activities and are covered in the PPB statements for these activities.

(2) Planning Assumptions

i) Although the present level of process development and operational research being done by industrial, government and other research organizations is probably sufficient for the country's current needs, the effort will have to be stepped up beginning in 1974 or 1975 (7) when a rapid expansion is expected. New plants and plant expansions will be undertaken, which will be expected to incorporate the latest processing technology. The existence of a small corps of processing experts in Mines Branch with good liaison with the industry will greatly facilitate efficient and orderly expansion of the industry.

ii) Exploration for new uranium deposits will occur concurrently with, or slightly before, expansion of the industry. It may be expected that some at least of the deposits found will present processing problems for which solutions will have to be found.

iii) It is important that Canadian uranium producers be in a position to capture markets early, as it is easier to retain captured markets than to break into new ones.

(3) Relation to Other Mines Branch Activities

The projects related to radioactive ores are carried out exclusively in the Extraction Metallurgy Division.

(4) National Need

In the period 1942 to 1959, a huge industry was built up, and in the latter year the value of uranium concentrates produced exceeded that of all minerals except petroleum. The Department, through the work of the Geological Survey and the Mines Branch, received wide acclaim for its part in this development. Work of a similar nature is not being carried on now to any great extent. If governments are to aid in the search for additional uranium resources required to support an expanding uranium industry, then it is likely that basic technical and research services that were normal in the past will need to be developed again.

Conservation of energy resources is one of the prime responsibilities of government. In light of the size of the projected demand for uranium, it would seem advisable to maintain a continuing surveillance of Canada's uranium resources and the technology needed to exploit them, primarily to provide assurance to the domestic nuclear power industry of an adequacy of supply, but also to assist in promoting the export of uranium resources surplus to domestic requirements (7).

(5) Alternatives

The following alternatives are available to the Canadian Government for the encouragement of the process studies, relevant to radioactive ores, which are needed to maintain the process technology at a level which will make sound resource management and energy policies meaningful.

a) Encourage industry through some form of government financial support to conduct the process studies required to meet future national needs.

b) Have the work done in universities or in independent research organizations under government contract.

c) Limit government financial support and assume that industry will develop the needed technology as it is required, largely at its own expense.

d) Support a well-equipped, multi-disciplined government laboratory charged with the responsibility of developing technology 5 to 10 years ahead of its need by industry in meeting national goals.

(6) Criteria

The most suitable courses of action are those which will ensure that process technology is always such that the government's programs for such things as resource management and environmental protection, as applied to radioactive ores, are not hampered by incomplete or unknown technology. In addition the approaches taken should ensure that all aspects of a given problem are considered.

(7) Preferred Courses of Action

a) Provide Canadian Government support for those industries large enough to have an effective process development group through grants or tax incentives in conducting work relevant to their individual, immediate interests.

b) Support a government process development laboratory to conduct the work not being done by the larger companies, but which appears to be needed to meet foreseeable national needs.

(8) Project Titles and Technical Objectives

The Processing of Low-Grade Radioactive Ores

This project involves a study of percolation leaching of uranium ore with bacterially active leaching solutions. Methods for recovering the uranium from these leach solutions by solvent extraction and ion exchange methods are also being investigated. The purpose of the work is to check the feasibility of some form of in situ leaching method which, if successful, could lead to greatly reduced production costs (1, 2).

Other development studies are directed towards the development of a solvent-in-pulp process for recovering the uranium from solution without the need to separate the waste solids from the uranium solution. Such a process would be cheaper than currently-used processes (3, 4).

This project also includes the development of special analytical techniques as required by the project, more precise methods for umpire analyses, and general chemical, metallurgical and mathematical support services (5, 6).

Finally, the project includes the sub-sub-activities designed to ensure an awareness in all sectors of government, industry and university of trends and changes in technology, national needs and social needs as they relate to the processing of radioactive ores. These sub-sub-activities include technical consultation, technical information services, advisory services, and the provision of means for information exchange (2, 4, 9, 10).

(9) Projected Costs and Scheduling

	Man Years per Year			Cost per	Total Cost
	72/73	73/74	74/75	Man Year	for 3 Years
Professionals	3.9	3.9	3.9	15,000	175,500
Technicians	4.6	4.6	4.6	8,000	110,400
					285,900
Plant, service and overhead					299,100
					585,000

(10) Benefits

It is forecast that world uranium demand will pick up in the latter half of the present decade with Canadian production increasing by a factor of two to three by 1960. Even a modest expansion of only 50 per cent would mean that new or expanded plant capacity capable of processing an additional two million tons of ore a year would be needed. If this new capacity is to use cheaper methods, the process development work must be done now. If the development work and other projects being done at Mines Branch should result in lower production costs, it would improve Canada's competitive position on the world market.

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5. D. Barkley, "The Determination of Amine Solvent Extraction Reagents in Ore Solutions and in the Aqueous and Solid Phases of Pulps or Slurries", EMD Information Memorandum EMI 70-5, Apr. 1970.

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7. R. M. Williams, "Canada's Future in Uranium Supply", Mineral Resources Branch, Mineral Information Bulletin MR 98, 1969.

8. W. A. Gow and G. M. Ritcey, "The Treatment of Canadian Uranium Ore", Bulletin of the CIMM, Dec. 1969.

9. Proceedings of Meetings of the Canadian Uranium Producers' Metallurgical Committee, EMD Information Memoranda EMI 70-10, EMI 71-2. (These meetings have been held at least twice a year since 1960).

10. H. W. Smith, "Field Trip to Elliot Lake Area", EMD Visit Memorandum EMV 70-1. (For purpose of exchanging information with Elliot Lake mine operators).

11. Private communication.

D - PHYSICAL METALLURGY DIVISION

SUB-ACTIVITY 1: PIPELINE RESEARCH

(1) Purpose

The objective of the Mines Branch energy activity is to promote the fullest and best use of Canada's energy resources within the framework of a strong domestic industry and of a clean environment. The Physical Metallurgy Division is engaged in one specific aspect of the problem and the purpose of this sub-activity is to ensure the most effective transportation of Canada's oil and gas resources with the minimum risk of environmental pollution. The title of the project is "Metals and Alloys for Use in Fuel Transmission Pipe Lines".

(2) Background and Scope

Oil and gas represent two of Canada's most important non-renewable resources, both from the point of view of domestic consumption and with regard to their potential export value. The development and transportation of these resources has been in progress for many years, but the relatively recent discoveries in the North (including the Arctic Islands) have had widespread repercussions in Canada and the United States. It is estimated that reserves of approximately 60 billion barrels of oil and 350 trillion cubic feet of natural gas exist in northern Canada—six times the present proved oil and gas reserves in the rest of the country.

In view of the magnitude of these resources and the contribution they can make to the economy, their efficient and rapid transportation to the Canadian consumer and the American market is a matter of obvious importance. It is essential, therefore, that the structural integrity of the pipe lines should be maintained under the rigorous climatic conditions of the Arctic, thus avoiding an expensive interruption in the flow of oil or gas and the associated pollution of the environment. Since it is not possible to guarantee complete integrity, consideration must also be given to repair procedures which may be required at remote locations and under adverse conditions.

(3) Situation

Considerable experience and knowledge has been gained from the construction and operation of pipe lines in the southern areas of Canada; nevertheless, breakdowns still occur. Most pipe lines at the present time have a diameter of 36 in. or less and a yield strength in the range 52,000-65,000 psi. In order to increase the output, it is expected that the northern pipe lines will be 48-54 in. in diameter, and will have a yield strength in the range 70,000-90,000 psi. Furthermore, in view of the permafrost problem, portions of the lines will have to be constructed during the winter. The necessity of higher integrity and the lower ambient temperatures impose more stringent toughness requirements.

Since commercially-available pipe is not satisfactory for the northern sections of the line, improved pipe must be developed, closer control of production and fabrication must be studied, and performance characteristics under service conditions must be evaluated. It is important to realize that the aspects to be covered range from the initial production of a suitable steel and its conversion to plate, through the forming and welding of large-diameter pipe to the field-welding and behaviour of the finished product.

(4) Relation to Other Mines Branch Activities

The Metals and Alloys for Use in Fuel Transmission Pipe Lines Project is one of several Mines Branch projects associated with the development and characterization of improved structural materials and with the prevention of environmental contamination. Their common objective is to ensure that the best use is made of Canada's energy resources with the optimum benefit to the economy and the minimum hazard to personnel and the environment.

(5) Alternatives

The project under discussion essentially involves a large amount of applied research in all its aspects. The development of improved pipe to meet the challenge of the Canadian North could be carried out entirely by individual companies in the industry and would necessitate studies of processing controls, strength characteristics and reliability, resistance to stress corrosion, shock and vibration, and full-scale bursting tests. Apart from the fact that facilities for such comprehensive studies are not normally available to individual Canadian companies, it must be recognized that some degree of bias is inevitably associated with commercial enterprises, and that due to proprietary interest communication of the results of their research is generally limited.

(6) Criteria

As in most cases of product development, the criteria are essentially those of economy, efficiency and expediency, bearing in mind that it is desired to obtain the maximum oil and gas output in the minimum of time with the maximum of structural integrity.

(7) Preferred Course of Action

Since the Mines Branch has developed a considerable background of expertise in the pipe-line field over many years, has acted as consultant to the National Energy Board on metallurgical aspects of fuel transmission lines, has the necessary facilities for the applied research involved, and is an unbiased federal body, it was considered logical to proceed with the project along the lines discussed below. It is worth noting that the Branch is also engaged in a project on metals and alloys for use in the Arctic, and the inter-relationship is self-evident.

(8) Project Title and Technical Objectives

Metals and Alloys for Use in Fuel Transmission Pipe Lines

This project can be broadly divided into two parts, one dealing with the development of improved steels for gas and oil pipe lines and the other dealing with the fabrication and performance of the actual pipe. In all of this work emphasis is placed on the effect of the Arctic environment on properties, performance and maintenance (e. g. welding under Arctic conditions).

The material development aspect involves studies of the influence, composition and processing variables, with the objective of obtaining a weldable pipe line steel of improved strength and toughness.

The fabrication studies involve work on the effect of forming and welding procedures, and of service parameters such as pressure, temperature, vibration, and corrosion, on the performance of the fabricated pipe. The objective is to establish realistic acceptance criteria for structural integrity. Sub-projects covering these various aspects are in progress.

(9) Projected Costs and Scheduling

	Man Years per Year			Cost per Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	6	6	6	15,000	270,000
Technicians and Hourly Rate	6	6	6	8,000	144,000
					414,000
Plant, Service and Overhead					233,100
					647,100

(10) Benefits

While it is impossible to give an estimate of the benefits to be derived from this project in terms of dollars, their potential values must obviously lie in the millions. The fuel and gas resources are available and must be transported as efficiently and expeditiously as possible both to the Canadian consumer and the American market. A satisfactory solution, resulting in increased flow and higher structural integrity and reliability, will benefit the economy directly. Secondary benefits will be derived from the prevention and minimizing of leaks and seepage by the consequent reduction both in expensive "shut-down" time and in irreparable damage to the northern environment.

ENERGY ACTIVITY: 3-YEAR FORECAST

SUB-ACTIVITY AND SUB-SUB-ACTIVITY	PTO	Man Years			Cost/ Man Year	Total 3 Years
		72/73	73/74	74/75		
A. Fuels Research Centre						
New Technology in Beneficiation of Low Grade Petroleum Resources						
Hydrocarbon Processing and Catalysis Research	P	12	15	15	15,000	$ 630,000
	T	12	14	14	8,000	320,000
	O					930,000
						$1,880,000
Evaluation of Fossil Fuels						
Service, Liaison and Consultation	P	2	2	2	15,000	$ 90,000
	T	1	1	1	8,000	24,000
	O					72,000
						$ 186,000
Evaluation of Petroleum and Gas Resources	P	3	4	4	15,000	$ 165,000
	T	7	11	11	8,000	232,000
	O					422,000
						$ 819,000
Solid Fuel Analytical Evaluation	P	3	4	4	15,000	$ 165,000
	T	4	8	8	8,000	160,000
	O					311,000
						$ 636,000
Dust Explosibility Research	P	-	-	-	--	--
	T	1	1	1	8,000	$ 24,000
	O					37,000
						$ 61,000
Evaluation of Coal Resources	P	0.5	0.5	0.5	15,000	$ 23,000
	T	1	1	1	8,000	24,000
	O					45,000
						$ 92,000
Evaluation of Peat Resources	P	1.5	1.5	1.5	15,000	$ 67,000
	T	-	-	-	--	--
	O					26,000
						$ 93,000
Evaluation of Fine Structures	P	1	1	1	15,000	$ 45,000
	T	1	1	1	8,000	24,000
	O					54,000
						$ 123,000
Sub-Totals		50	65	65	--	$3,890,000

P = Professional T = Technician O = Overhead including equipment and supplies

SUB-ACTIVITY AND SUB-SUB-ACTIVITY	PTO	Man Years			Cost/ Man Year	Total 3 Years
		72/73	73/74	74/75		
Research on Bituminous Substances	P T O	4 1	4 1	4 1	15,000 8,000	$ 180,000 24,000 106,000 $ 310,000
Total, Fuels Research Centre		55	70	70	--	$4,200,000
B. Metals Reduction and Energy Centre						
Coal Beneficiation Research	P T O	3 6	3 6	3 6	15,000 8,000	$ 135,000 144,000 161,000 $ 440,000
Carbonization Research 1) Coal Processing, Coking Processes and New Coal Applications. 2) Industrial Investigations for Coal and Coke Industries. 3) Service.	P T O	9 14	9 14	9 14	15,000 8,000	$ 405,000 336,000 111,000 $ 852,000
Pyrometallurgy Research 1) Improvement of Electric Furnace Efficiency. 2) New Processes for Sulphide Ores. 3) Marketable Products for Unusual Ores and Waste Materials.	P T O	4 5	4 5	4 5	15,000 8,000	$ 180,000 120,000 215,000 $ 515,000
Special Research	P T O	4 2	5 3	5 3	15,000 8,000	$ 165,000 64,000 246,000 $ 475,000
Total, Metal Reduction and Energy Centre		47	49	49	--	$2,282,000

SUB-ACTIVITY AND SUB-SUB-ACTIVITY	PTO	Man Years			Cost/ Man Year	Total 3 Years
		72/73	73/74	74/75		
C. Extraction Metallurgy Division						
Pyrometallurgy Research, Analysis	P	0.5	0.5	0.5	15,000	$ 22,500
	T	0.35	0.35	0.35	8,000	8,400
	O					30,600
						$ 61,500
Radioactive Mineral Resources	P	3.9	3.9	3.9	15,000	$ 175,500
	T	4.6	4.6	4.6	8,000	110,400
	O					299,100
						$ 585,000
Total, Extraction Metallurgy Division		9.35	9.35	9.35	--	$ 646,500
D. Physical Metallurgy Division						
Pipeline Research	P	6	6	6	15,000	$ 270,000
	T	6	6	6	8,000	144,000
	O					233,100
Total, Physical Metallurgy Division						$ 647,100
Total, Energy Activity		124	141	141	--	$7,775,600

4. ENVIRONMENTAL IMPROVEMENT ACTIVITY

OBJECTIVE

To reduce pollution (air, water and land) arising from mining and metallurgical operations, including the conversion of energy minerals.

BACKGROUND AND SCOPE

Canadian mining and metallurgical companies have three principal pollution problems, namely air pollution control, water pollution control and land pollution control.

Air pollution control is concerned mainly with the reduction of particulate material and of sulphur dioxide discharged into the atmosphere.

Most companies face the problem of particulates to a greater or lesser degree, as for example in the crushing of rock, the roasting and smelting of ores, the burning of fuel, the making of coke and the smelting of aluminum. Although the technology of dust collection is well advanced, research is needed particularly in the collection of the finest particles. In some cases problems exist in collecting the exit gases from the various operations, and the final disposal of the collected material is itself sometimes a problem. Companies have made major improvements in dust and fume control in recent years, but for some operations the limits of current technology are being approached.

The mining and metallurgical industry is not the only, nor the major emittor of sulphur dioxide to the atmosphere, for sulphur dioxide is produced whenever sulphur-bearing fuels are burned. Much of the sulphur dioxide produced by the industry is now being recovered as sulphuric acid or liquid sulphur dioxide. However, there are limits to the amounts of these products that can be utilized and, in addition, the treatment of dilute gas streams is expensive. Improved methods are urgently required for removing sulphur oxide from these dilute smelter gases as well as from combustion gases generated from the burning of fossil fuels containing sulphur. For non-ferrous smelters, replacement of reverberatory furnaces by flash smelting units is one alternative, since the off-gas is then rich enough for economic recovery of the sulphur.

Some pyrometallurgical processes that produce sulphur dioxide can, in principle, be supplanted by hydrometallurgical processes, which produce sulphur in elemental form or as ammonium sulphate. Pilot plant scale research is going forward to establish the technical and economic feasibility of such processes.

In water pollution control, the reduction of suspended solids in liquid effluents is a problem common to most mining and metallurgical operations. In general, it is adequately dealt with by providing thickeners and settling basins, by the use of flocculants, and by re-circulating and re-using water to reduce the total outflow. Occasionally, extremely fine particles down to colloidal size are encountered, which cannot be settled by existing techniques in spite of a considerable amount of research. Where the particles are coloured, as in iron ore mining operations, the presence of these colloidal particles is obvious to the eye.

A common pollution problem in the mining industry arises from the presence of dissolved salts and acids in mine waters and seepage waters from tailings dams prior to discharge. This is a frequently occurring problem which is currently dealt with principally by treating the waters with lime which neutralizes the acids and precipitates the heavy metals as a sludge. However, the precipitated sludge is difficult to dispose of and research is needed to find ways of obtaining a more easily-handled material at an acceptable cost.

Cyanide mills have no difficulty in disposing of dilute cyanide solutions, since the cyanide oxidizes rapidly on exposure to air. Uranium mills have a special problem with dissolved radioactive materials, and these are precipitated through the use of barium chloride.

Land pollution resulting from the operation of underground mines is confined almost entirely to tailings dams. Good progress has been made in getting vegetation to grow on disused tailings dams, thus eliminating the blowing of dust, reducing seepage and sometimes yielding useful crops. The stability of large tailings dams is a subject of continuing engineering concern for the environment.

In open pit and strip mining operations the disturbance to the land is much greater than with underground mining, but the end result is not necessarily bad. Valuable crops of grasses and trees have been grown on piles of waste materials, and disused pits, which soon fill with water, have been stocked with trout and black bass. Plans have been made for housing developments in some worked-out gravel pits near metropolitan centres.

Although the mining and metallurgical industries and the provincial governments have a large measure of responsibility for environment improvement, the federal government also has a strong interest, particularly in finding ways to deal with many of the difficult technological problems encountered. Thus, although further developments for controlling air pollutants can be anticipated, it would be prudent to assume that such developments will only keep abreast of the increasing burden of atmospheric pollutants unless better controls at the source can be obtained. That is, the most promising means for improving environmental quality often lies in preventing the production of pollutants in the first place.

The primary activities of the Mines Branch in contributing to the solution of this vital national problem, are to determine the nature and amount of pollutants being released to the atmosphere and to carry out scientific and engineering research and development on acceptable control measures where warranted.

DESCRIPTION OF ENVIRONMENTAL IMPROVEMENT ACTIVITY

The social objectives of this activity are:

(1) To insure the elements of simple survival.
(2) To prevent disease and poisoning.
(3) To maintain an environment suited to man's efficient performance.
(4) To preserve comfort and the enjoyment of life.

In order to attain these objectives, the Branch conducts its environmental improvement investigations through three sub-activities:

(1) Characterization of pollutants and development of pollution-free processes.
(2) Dispersion and disposal of effluents.
(3) Reduction of pollution in mines.

In this report Sub-Activities (1) and (2) are combined.

SUB-ACTIVITY 1: CHARACTERIZATION OF POLLUTANTS AND DEVELOPMENT OF POLLUTION-FREE PROCESSES

SUB-ACTIVITY 2: DISPERSION AND DISPOSAL OF EFFLUENTS

1. CANADIAN COMBUSTION RESEARCH LABORATORY

OBJECTIVE

To protect the air, water, and land environment from pollution produced from the combustion of conventional fuels and combustible wastes in any heat process and from mining and metallurgical operations.

BACKGROUND AND SCOPE

As population grows it concentrates, according to the present scheme of things, in urban areas. At the same time, some people appear convinced that the panacea of our time is to consume more and more of the world's natural resources including energy. We have now arrived at a stage where the majority of the population depends for survival on the application of technology.

The basis of technology is minerals and energy derived from the burning of conventional fuels. Fuel combustion, in which pollutants are produced according to unalterable natural physical laws, is Canada's largest source of air pollution.

Two pollution inflationary forces are at work, increasing population and increasing consumption of fuel and energy per person. In Canada between 1946 and 1970, fuel consumption per person increased at the rate of nearly 2 per cent per annum while population increased at the rate of 2.52 per cent per annum. Gross national product increased at a rate double that of population growth and slightly higher than the rate of increase of fuel consumption. At the 1968 fuel consumption rate and based on 1968 combustion technology, some 330 million tons of pollution including carbon dioxide is dumped into the air from fuel combustion and major mineral processes. This is 15.68 tons per year for every Canadian and is a measure of the affluence of Canadians.

Affluence and a high level of technology result in a high level of wastes. Some are being recycled and re-used, but in attempting to cope with rapidly increasing quantities of solid waste without violating increasingly stringent anti-pollution legislation, many municipalities and industries are turning to incineration. A confusing array of incineration equipment is now available, ranging from small units of indigenous design suitable for apartment buildings or commercial establishments to large units of European design suitable for generating substantial quantities of steam or electricity. It was necessary, therefore, to rationalize some of the more popular designs in each class of incinerator including systems for thermal destruction of industrial wastes.

The combustion process, at best, produces large quantities of effluent gases which must be adequately dispersed in the air environment. Also, considerable particulate matter is produced which must be separated from the combustion gases either in a dry state or in water of a scrubber system. Therefore, proper selection of chimney height and design of particulate separation systems are critical.

(1) Situation

The air pollution problem, in particular, would be much worse than it is were it not for advances in fuel and combustion technology; and yet, as stated above, the total pollution burden is increasing. This is bringing upon us stringent pollution controls which have the effect of increasing the demand for premium fuels (natural gas, crude oil, and refined oil) and clean flames from burning the high polluting fuels (residual oil and coal). In the first case, research on burners for conversion purposes and in the second case research to produce blue-flames (clean type of flame) are essential both for abating pollution at all flame sources and to conserve these critical non-renewable resources.

(2) Planning Assumptions

The trend of our time is to consume more natural resources, to use more energy, and to enjoy more of the luxuries which our constantly improving technology makes available. At the same time, it is reasonable to expect that population will continue to increase at the rate of 2.5 per cent per annum. These two trends will result in continued proliferation of pollution sources and increased fuel consumption. It is highly unlikely that either of these trends will be curbed by government legislation. Therefore, there is no alternate to increasing research effort to produce clean flames and clean combustion processes and to making use of wastes by re-cycling or as ingredients in useful products.

(3a) Relation to Other Mines Branch Studies

Heat from the burning of conventional fuels is the basis of most mineral and metallurgical processes. Therefore, it is planned to continue collaboration with other Divisions of Mines Branch and to engage in joint projects in the national interest. Specialized combustion and combustion gas sampling and analysing methodologies developed by CCRL will be freely available to other Divisions.

(3b) Relation to Industry and Others

The CCRL research facilities are already available to PhD candidates from any Canadian university. Similar arrangements will be considered for industry through the formation of a research association to be negotiated through senior administration. Presently, the CCRL provides a research base and a consulting service to industry and government departments, both federal and provincial.

(4) National Need

Minimizing pollution from mineral processing and fuel combustion sources is a technical-scientific problem that will respond only to technical-scientific treatment. For this, a centre of research excellence is needed, such as the Mines Branch.

The objective of more jobs for more people requires more industry and if this is to be achieved without more pollution greater priority must be given to research on the processes which are the source of pollution.

(5) Alternatives

Alternatives are to curtail industry, to reduce luxuries (standard of living) or to plan on rapid deterioration of the air, water, and land environments.

(6) Preferred Courses of Action

There seems to be no choice but to proceed with the current modest but intensive, engineering-scientific research program at the Mines Branch and to collaborate with government departments, both federal and provincial, industry, universities, and international research agencies such as the International Flame Research Foundation in Holland. At the same time, it seems important to prevent duplication of effort by keeping abreast of developments through active participation in technical societies, national committees and international committees.

A close working relationship with industry is preferred thereby pooling engineering production and research talent.

Finally, a high priority criterion in the conduct of this research is probing methodology and instrument development.

(7) Project Titles and Technical Objectives

a) Characterizing Pollutants in Relation to Flame Properties

Over the years, the CCRL has developed instruments to continuously measure constituents of combustion gases (CO, CO_2, O_2, SO_2, NO_2, NO_x, H_x, C_y) and batch sampling methods for SO_3 and particulates. Probes for measuring the fluid mechanics of flames (aerodynamics) and thermodynamic properties of flames (heat flux and radiation) have been acquired through support of the International Flame Research Foundation. A special research tunnel furnace, in which flames may be studied, has been designed and constructed by CCRL making it one of the best equipped in the world for flame research.

These facilities make it possible to study the effects of flame properties on pollutant emissions and the first pollutant to be studied is NO. Its formation and decay will be rationalized under all conceivable conditions.

b) Blue Flame

Having the capability to measure the fluid mechanics of flames it has been found that aerodynamics has an overwhelming influence on chemical kinetics and heat transfer. This is achieved through control of the oxygen diffusion mechanism which has resulted in the production in the laboratory on a small scale, of a clean flame called a "blue flame" when burning No. 2 furnace oil. This concept is being applied to large burners and lower grade (quality) fuels by rationalizing burner designs using the flame research tunnel furnace.

An attempt will be made to develop a standard burner-design criterion based on either momenta ratio or swirl number.

The present, small-scale blue flame will be developed into a commercial burner for domestic space heating.

c) Combustion Process Phenomena

Fundamentals, elucidated from basic research, are related to practice in over-all combustion phenomenological studies in both dry and slagging systems using a laboratory research boiler. The mode of transport of alkali ash constituents, mechanism of ash deposition, control of electrical resistivity of particulates for efficient separation in gas streams, SO_2 to SO_3 conversion, NO to NO_2 conversion and decay, rate of acid build-up and many more, are rationalized. The resulting criteria are applied to the design of combustion systems for burning all fuels (coal, lignite, crude oil, residual oil, refined oil, natural gas and wastes) for power generation, industrial steam raising and heat processes.

d) Incineration

As our society becomes more affluent there are more wastes to be disposed of. Recycling or re-using these wastes is first attempted but this is limited to relatively few materials. As a result, incineration is becoming widespread and this project rationalizes the incineration process in relation to the thermo-physical properties of the waste.

e) Plume Dispersion (Chimney Height Standard)

The minimum quantity of combustion gases permitted by natural physical laws is a very large amount which must be dispersed in the atmosphere to prevent ground level fumigation. Consequently, an empirical equation was developed by CCRL for the selection of chimney height to provide adequate dispersion. However, it could not be verified because there were no data available on the dispersion capacity of Canadian "air sheds". As a result, CCRL was forced to develop an aerial probing methodology to measure the dispersion of hot plumes from chimneys and this methodology is providing the needed data. These data when reduced, will possibly revise the present empirical equation and in a revised form it may be applied with confidence except in the far north and Arctic.

f) Field Evaluations

The probing and measuring methodologies developed in the CCRL are in demand by industry to analyse actual industrial processes with the object of developing design criteria for pollution abatement apparatus. Power plants, oil refinery and steel processes find this expertise of particular value in meeting increasingly stringent pollution control regulations.

(8) Projected Costs and Scheduling (1972-1975)

a) Characterizing Pollutants in Relation to Flame Properties

	Man Years per Year	Cost/Man Years	Total Cost for 3 Years
Professionals	2	15,000	$ 90,000
Technicians	1	8,000	24,000
Plant, service, overhead			114,000
			$228,000

b) Blue Flame

	Man Years per Year	Cost/Man Years	Total Cost for 3 Years
Professionals	1	15,000	$ 45,000
Technicians	0.5	8,000	12,000
Plant, service, overhead			45,000
			$102,000

c) Combustion Process Phenomena

	Man Years per Year	Cost/Man Year	Total Cost for 3 Years
Professionals	2	15,000	$ 90,000
Technicians	1	8,000	24,000
Plant, service, overhead			114,000
			$228,000

d) Incineration

Professionals	1	15,000	$ 45,000
Technicians	0.5	8,000	12,000
Plant, service, overhead			30,000
			$ 87,000

e) Plume Dispersion

Professionals	1	15,000	$ 45,000
Technicians	1	8,000	24,000
Plant, service, overhead			81,000
			$150,000

f) Field Evaluation

Professionals	1	15,000	$ 45,000
Technicians	1	8,000	24,000
Plant, service, overhead			15,000
			$ 84,000

(9) Benefits

a) Characterizing Pollutants in Relation to Flame Properties

The flame properties that produce the least pollution will be determined for all types of fuels, burners and processes. Then it will be possible to rationalize burner designs systematically.

b) Blue Flame

The present laboratory blue flame is ideally suited to domestic heating and its commercial development should go a long way to reducing this source of pollution which is 20 per cent of the total on a national basis.

Expanding the concept to commercial and industrial scale will conserve fuel resources to a significant extent and reduce pollution at flame sources as well. The research will disclose burner design criteria for the guidance of pollution control agencies.

c) Combustion Process Phenomena

Design criteria will be developed for complete combustion systems for all fuels to produce minimum pollution and to provide maximum life at lowest cost for the over-all process. This includes high fuel to useful heat conversion efficiency, protection of heat transfer surfaces, removal of particulate matter and all other criteria.

d) Incineration

Incinerator designs will be rationalized for minimum pollution emission and minimum (sterile) residue. The way will be shown for safe disposal of toxic combustible wastes with the exception of heavy metals like lead.

e) Plume Dispersion

The chimney is a critical part of any flame or heat process. This project will make it possible to select the proper height to ensure adequate dispersion at lowest cost.

f) Field Evaluation

This is a useful way of relating fundamentals to practice. It helps consulting engineers and industry to take economically and technically feasible measures to meet new pollution control regulations that often catch them unprepared.

(10) Estimate of Output/Input Ratio of Research Projects

		Annual Basis	
	Output*	Input	Ratio
a) Characterizing Pollutants in Relation to Flame Properties	150, 000	76, 000	2:0
b) Blue Flame	100, 000	34, 000	3:0
c) Combustion Process Phenomena	200, 000	76, 000	2:6

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*Output is defined as legitimate charge for work which may have increased value to the user through savings year after year, additional production and intangibles such as cleaner air.

		Annual Basis	
	Output*	Input	Ratio
d) Incineration	150, 000	29, 000	5:3
e) Plume Dispersion	150, 000	50, 000	3:0
f) Field Evaluation	150, 000	28, 000	5:3

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2. EXTRACTION METALLURGY DIVISION

(1) Situation

The introductory section covering the general background and scope of the Mines Branch Environmental Improvement Activity describes the major problems faced by the mining and metallurgy industry in fulfilling its obligations to reduce environmental degradation. The Extraction Metallurgy Division (EMD), because of the experience and background of its staff, can contribute considerably to finding solutions to some of these problems. Hydrometallurgical methods hold the hope of recovering base metals from sulphide concentrates without the production of sulphur dioxide (1). Knowledge of metal-oxygen-sulphur systems can be brought to bear on the problem of adsorbing sulphur dioxide from gas streams by metal oxides (2). Experience in the oxidation and leaching of metal sulphides is needed in solving the problem of acid mine water formation and acid seepage from sulphide tailings dams. Numerous other extractive metallurgy techniques such as ion exchange, cementation, neutralization and solvent extraction may be useful in solving the problem of reducing metal content of aqueous effluents (3).

In deciding whether a project is part of the Environmental Activity Program or not, the EMD takes the view that the development of entirely new processes that could be used in place of those that produce undesirable pollutants are not part of the Environmental Improvement Activity. Although the elimination of pollutants is an important aspect of such process development studies, there are usually several other important considerations that do not have an environmental context. Because of this, EMD projects that have as their objective the development of an entirely different process to those now generally in use are considered to be part of the Minerals and Metals Technology Activity. These include the several projects now being conducted in EMD at an annual cost of $200, 000 to develop processes that produce elemental sulphur instead of the undesirable sulphur dioxide gas.

The EMD does consider that the development of processes that could be added to a conventional process to reduce or remove pollutants produced by the original process is an Environmental Improvement Activity. Examples of "add-on" processes are processes such as neutralization or ion exchange methods applied to remove pollutants from aqueous effluents, or processes for the removal of sulphur dioxide from stack gases. Those EMD projects which are aimed at the development of "add-on" processes are the ones covered by this statement of activities for the Environmental Improvement Activity.

The statement has been made many times that each industry must solve its own pollution problems regarding its waste streams. This is fair and the mining and metallurgical industry is reacting to it in a responsible manner. However, there is much to be done and, because of the urgency involved, industry is attempting to solve its immediate problems by applying or modifying known "add-on" process technology. Because of lack of time and personnel with the proper background, industry is not able to delve deeply into the development of possible new approaches. At the same time the industry is faced with the possibility (as has happened in the U. S. A.) that new regulations may be set which cannot be met by known technology. Obviously it is of great importance and urgency that government ensure that necessary new "add-on" technology is developed so that its goals for environmental improvement can be met at a reasonable cost.

(2) Planning Assumptions

a) As the efforts for environmental improvement increase, the mining and metallurgical industry will face increasingly stringent effluent control regulations which, in turn, will require new technology.

b) The industry will look to the government, which is setting regulations, for advice and help in developing the required technology. Although it would be unrealistic for government laboratories to do all of the development, it will be necessary for the government to ensure that its own staff conducts selected projects and promotes liaison with industry so that it will be continually up-to-date on the technological situation.

(3) Relation to Other Mines Branch Studies

Obviously, development work directed towards new metallurgical processes must take into consideration the methods to be used in cleaning up the effluent gas and water streams from the process. Consequently, regardless of the characteristics of the main process study, many of the pollution control problems would be related to the EMD activities.

(4) National Need

Both the government and a large segment of the Canadian people are convinced that control of the environment has a high priority in the list of national goals. In the absence of the technology required to meet national pollution standards, the setting of national objectives will be meaningless. It is therefore extremely important that governments adopt a plan to ensure that technological development keeps pace with the regulations that are found necessary to enact.

(5) Alternatives

a) Provide Canadian Government support for companies or research organizations through grants or tax incentives in conducting work in the field of effluent control technology to develop methods that will be required immediately to meet the national goals.

b) Support a well-equipped, multi-disciplined government laboratory charged with developing the necessary technology, both immediate and for the future.

c) Support long-term studies related to effluent control problems through the universities.

(6) Criteria

The most suitable courses of action are those that ensure that research in pollution control technology is both relevant and efficient, that both short-term and long-term needs are provided for, and that the problems of both large and small industries are dealt with adequately, so that industry can always meet the goals set by government.

(7) Preferred Courses of Action

a) Support those industries large enough to have effective process development groups, through tax incentives or grants, to aid them in meeting their own immediate problems.

b) Support a well-equipped, multi-disciplined government laboratory to assist the smaller industries, that lack well-equipped research and development facilities, particularly with advice in meeting problems, but also where necessary with practical assistance. Such a laboratory should also concern itself with the problems that are foreseen for the future, as industry grows and changes, and as government goals change.

c) Support universities in training students in pollution control technology, and in doing longer-range research in pollution control techniques.

(8) Project Titles and Technical Objectives

a) Minimizing Gaseous Pollutants

Part of the present work is to make a systematic study of those metal oxide systems that have the greatest ability to trap sulphur dioxide from the mixture of gases that occurs in ore roasting and fuel burning. In addition methods of applying suitable metal oxides are being investigated. The removal of sulphur dioxide from stack gases with calcium oxide is not new, but it is hoped that this study will result in more effective utilization of calcium carbonate or calcium oxide or, alternatively, in more effective absorbants (4, 5).

Other projects include an investigation into the factors that control arsine evolution from arsenic-bearing solutions during cementation operations. The objective of the study is to develop methods to prevent evolution of this gas. Another project under this heading has as its objective the reduction of NO_x productions in steam boiler operations (7).

b) Minimizing Aqueous Pollutants (2)

In this project studies are underway to determine the technical and economic feasibility of several possible methods for recovering heavy metal and other dissolved contaminants from aqueous effluent streams. A comparison of ion exchange with neutralization for removing zinc and copper is being investigated. In another study the objective is to determine the possibility of recovering sulphite and sulphate from aqueous effluent for recycle as sodium hydroxide.

Another aspect of this problem is the development of methods that will reduce or eliminate the problem of acid water seepage from tailings ponds.

c) Consultative, Advisory and Liaison Projects

Finally, the project includes the projects designed to ensure an awareness in all sectors of government, industry and university of trends and changes in technology, national needs and social needs as they relate to the treatment of gaseous or aqueous effluents from the mining and metallurgical industry. These projects include technical consultation, technical information services, advisory services, and the provision of means for information exchange.

(9) Projected Costs and Scheduling

a) Minimizing Gaseous Pollutants

	Man Years per Year			Cost/	Total Cost
	72/73	73/74	74/75	Man Year	for 3 Years
Professionals	2.0	2.0	2.0	15,000	$ 90,000
Technicians	2.5	2.5	2.5	8,000	60,000
					150,000
Plant, service and overhead					74,000
					$224,000

b) Minimizing Aqueous Pollutants

	72/73	73/74	74/75	Cost/ Man Year	Total Cost for 3 Years
Professionals	3.0	3.0	3.0	15,000	$135,000
Technicians	1.0	2.0	2.0	8,000	40,000
					175,000
Plant, service and overhead					80,000
					$255,000

c) Consultative, Advisory, Liaison plus all Chemical Analysis and Similar Support Services

	Man Years per Year			Cost/ Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	0.85	0.85	0.85	15,000	$ 38,250
Technicians	4.3	4.3	4.3	8,000	103,200
					141,450
Plant, service and overhead					137,550
					$279,000

d) Totals of (a), (b) and (c)

Professionals	5.85	5.85	5.85	15,000	$263,250
Technicians	7.8	8.8	8.8	8,000	203,200
					466,450
Plant, service and overhead					291,550
					$758,000

(10) Benefits

Environmental improvement measures will add to the present cost of producing mineral concentrates and metal products. The actual cost incurred to do a specific pollution control job can vary widely depending on the method used. At the present the state of technology is not sufficiently advanced to give the industry a wide choice of approaches, and there is no guarantee that the ones available to it are necessarily the most efficient. The Mines Branch can contribute to this important aspect of mining and metallurgy by ensuring that development work is done on those possible pollution control measures which are not presently being considered by the industry in other research centres.

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3. MINERAL SCIENCES DIVISION

Characterization of Pollutants and Development of Pollution-Free Processes

(1) Situation

The emission of sulphur dioxide during the smelting of sulphide ores is one of the major pollution problems of the non-ferrous metallurgical industry. The rate of emission of SO_2 in Canada in the recent past has been estimated at 4.8 million tons annually. Considerable damage to vegetation results from this form of pollution.

(2) Planning Assumptions

More stringent application of air quality standards will require reductions in the quantity of SO_2 emitted by smelters. In general, two approaches can be taken to the reduction of SO_2 emissions: (a) changes in the method of processing so that SO_2 is not produced, and (b) the installation of methods for removing SO_2 from the gas stream going to the stack. Three projects have been undertaken, two in connection with new processing methods and one in connection with methods of removing SO_2 from gas streams.

(3) Relation to Other Mines Branch Studies

In the Extraction Metallurgy Division, investigations are being made on the application of chlorine metallurgy to sulphide ores in order that the production of SO_2 may be avoided. In one process, high temperature (300°-600°C) chlorination with HCl is used to produce metal chlorides plus H_2S. The H_2S can then be converted by the Claus process to elemental sulphur, which has a potential market value and which, unlike sulphuric acid or liquid SO_2, can be stored. In connection with this process, an investigation has been undertaken on certain aspects of the chloride-sulphide phase diagrams of Fe, Co, and Ni. Another process involves the leaching of the sulphide concentrate with hydrochloric acid to produce H_2S and a metal chloride solution. Pyrrhotite, a major constituent of sulphide ores, is being fractionated to provide material for leaching tests in the Extraction Metallurgy Division.

Work is also being done in the Extraction Metallurgy Division on the removal of SO_2 from gas streams. An extensive literature review of methods for SO_2 removal is underway in the Mineral Sciences Division. The results of this review will be available to the Extraction Metallurgy Division and to any others interested in SO_2 control.

(4) National Need

Non-ferrous smelters are located across Canada from New Brunswick to British Columbia. Many of these smelters are still emitting large quantities of SO_2.

(5) Alternatives

Many alternatives to the chloride processes mentioned above are possible. Sulphur dioxide could be recovered from present smelting operations, or from modified pyrometallurgical processes. More efficient dispersion of SO_2 using high stacks will reduce ambient concentrations at ground level. Other processes which do not produce SO_2, such as pressure ammonia leaching of nickel-copper concentrates, are either in operation or are possible. Considerable work on pollution abatement is being done by the companies concerned.

(6) Preferred Course of Action

Since the situations are different at various smelters with regard to type of ores, present process, possible alternative processes, meteorological conditions, and available markets for sulphur-containing by-products, there is unlikely to be any one universally applicable method of SO_2 abatement. Several lines of investigation will have to be pursued simultaneously, and selection made with regard to the particular local conditions.

(7) Project Titles and Technical Objectives

a) Phase Equilibrium Studies in the Fe, Co, Ni Sulphide-Chloride Systems

In order to support studies undertaken in the Extraction Metallurgy Division on the treatment of sulphide concentrates with HCl gas, an investigation is being made of some sulphide-chloride systems. In particular, it is necessary to establish whether there are any low-melting eutectics that might interfere with the chlorination process.

b) The Influence of Structure and Composition of Pyrrhotite on Its Reactivity

Pyrrhotites ($Fe_{1-x}S$) of different compositions are required for hydrochloric acid leaching tests that are being conducted in the Extraction Metallurgy Division. Natural pyrrhotites are being fractionated in order to provide material for experiments designed to determine whether different fractions, and in particular whether hexagonal and monoclinic pyrrhotite, behave differently during leaching. Mineralogical examinations of some leach residues are being made to aid the interpretation of the results of the leaching tests.

c) Methods for the Reduction of SO_2 Emission from Stack Gases

A literature survey is being undertaken to review the many methods that have been proposed for the reduction of the SO_2 content of stack gases from smelters and from thermal power stations. This review will provide a unified source of information on the topic.

(8) Projected Costs and Scheduling

Work on these projects was begun during the fiscal year 1970/71. Currently the three projects require the following:

	Man Years per Year	Cost/Man Year	Total Cost for 3 Years
Professionals	1.5	15,000	$ 67,500
Technicians	0.6	8,000	14,400
Equipment, service, overhead			83,100
Total			$155,000

The projects as outlined may be completed during 1972, but it is anticipated that extensions of these projects, or other environment-related projects, will continue with about the same input. The review of methods of SO_2 removal from gas streams will be kept up-to-date after the initial report has been issued.

(9) Benefits

The projects underway should aid in the development of metallurgical processes that are possible alternatives to smelting processes that currently emit SO_2. These processes, which would have H_2S as the sulphur-containing product, could be combined with processes that produce SO_2, and then, by the reaction of H_2S with SO_2, elemental sulphur could be recovered. The review on SO_2 removal from gas streams should aid in the selection and development of appropriate processes.

(10) Reference

Dibbs, H. P., Attendance at the Conference "Solutions for Pollution in an Urban Environment", held at Montreal, Quebec, Nov. 30-Dec. 1, 1970, MSV 70-15.

Dispersion and Disposal of Effluents

(1) Situation

During mining and milling operations fresh surfaces of sulphide minerals, particularly of pyrite and pyrrhotite, are exposed to the atmosphere and to water. Oxidation and dissolution of these sulphides often takes place to yield water with a high content of iron sulphates, sulphuric acid, and toxic heavy-metal ions. In particular, the finely-divided tailings from milling operations are exposed in tailings dumps, and seepage from these dumps may enter nearby streams.

(2) Planning Assumptions

Increased concern for water quality standards will require greater control on aqueous effluents coming from mining and metallurgical operations, and on water seeping from tailings dumps.

(3) Relationship to Other Mines Branch Studies

Investigations on the treatment of waste mine waters are being conducted in the Extraction Metallurgy Division with particular emphasis on the use of synthetic ion-exchange resins.

(4) National Need

Much practical work on monitoring and controlling aqueous effluents from mining and milling operations is being done by the companies concerned. Background information and investigations of new approaches are also required.

(5) Alternatives

Effluent water from mills can in some cases be recycled, but generally a certain amount of bleed-off will be required. The addition of lime is at present a commonly used method of neutralizing acid waters, with the consequent precipitation of iron and other heavy-metal ions as hydroxides. Alternative methods of treatment may be required, as liming produces an hydroxide precipitate that settles very slowly.

The growth of vegetation on tailings dumps will stabilize these against dusting, but more should be known about the chemical and microbial action in water percolating through the finely-divided tailings.

(6) Preferred Courses of Action

The investigation, at least on a preliminary basis, of new methods of treating acid mine water should be undertaken. The use of naturally-occurring clay minerals as ion-exchange media has been chosen for study. Investigation of the effect of mill tailings and slags on water percolating through them should be investigated.

(7) Project Titles and Technical Objectives

a) The Effect of Slag Heaps and Tailings on Water Pollution

A laboratory study of the effects of chemical and microbial action on tailings and synthetic slags is being conducted under controlled conditions using specially designed percolators. Synthetic slags will be used so that systematic studies of the effects of several variables, such as grain size, crystallinity, and composition of the slags, can be made. Changes in the pH, oxidation-reduction potential, and conductivity of the water used to leach the samples will be monitored.

b) Ion-Exchange Capacity of Some Silicate Minerals

The capacities of bentonite clays for the collection of base-metal cations by ion exchange from aqueous solutions will be studied. If these materials have an adequate exchange capacity they may be useful in overcoming pollution problems associated with mine drainage waters and drainage from tailings or slag heaps.

(8) Projected Costs and Scheduling

Currently the two projects require the following:

	Man Years per Year	Cost/Man Year	Total Cost for 3 Years
Professionals	2	15,000	$ 90,000
Technicians	1	8,000	24,000
Equipment, service, overhead			116,000
Total			$230,000

The project on the leaching of slags and tailings will, by its nature, be long-term and will continue at least through a 3-year period. Preliminary work on the ion-exchange capacity of bentonite has not yet been finished, and until this has been done the probable time to complete the project cannot be estimated with accuracy. However, it is expected that if the work is completed soon, another environment-related project would be undertaken.

(9) Benefits

The study of the leaching of slags and tailings should provide information on the probable seriousness of pollution by seepage from various types of solid metallurgical wastes, and may point to possible methods of control. The ion-exchange studies, if successful, could lead to methods of purification of waste waters from mining and metallurgical operations.

(10) References

No publications have been issued to date.

4. METALS REDUCTION AND ENERGY CENTRE

The following four minor projects of the Centre are concerned with environmental improvement:

(1) Air Pollution Abatement in Electric Smelting

Installation of the data-logger has been completed and this equipment is now in use, although additional signal lines will undoubtedly be required from time to time as the program develops.

This apparatus now appears to be very accurate and dependable, but a large number of hours of testing and trouble-shooting, with the assistance of the supplier, were required before this status was achieved. Most of the defects were poor contacts in parts of the electronic circuits.

The data-logger is currently used to gather flow and pressure-drop data on packed beds of various sizes of quartz rock. In the next phase of this study, submicron-sized silica dust will be introduced into the gas stream at elevated temperatures to study the filtering effect of these packed beds. It is hoped that these data will indicate that some air pollution abatement benefits can be realized by closer sizing of furnace charge ingredients.

(2) Volatilization of Lead Compounds from Flue Dust Recovered at the Noranda Smelter

At the request of the Noranda Research Centre, our rotary kiln was made available to investigate, on a pilot-plant scale, the removal of lead from pelletized flue dust, which is currently being collected at the Noranda Smelter. This flue dust is recirculated back to the smelter for recovery of copper. If the lead is not removed at this point, it will recirculate without an outlet until it escapes to the atmosphere.

This program was successful in that about 75 per cent of the lead was volatilized as lead compounds and collected in a baghouse. The program also defined operating temperatures, retention times and the furnace atmosphere necessary to volatilize these lead compounds. The project was discontinued when the Noranda management decided to install electrostatic precipitators, in which it expects to make a separation between the lead and the copper compounds in the original fume collection.

(3) Study of Airborne Coal Dust Suppression

This investigation was requested by Kaiser Resources Limited, and was designed as an initial study of the relative merits of certain reagents for surface coating of coal in railway cars in order to reduce the extent of coal dust emission during transport. In this study, various reagents were sprayed onto the surface of a flat container filled with coal, the container was placed in a wind tunnel and the loss of coal recorded. The results indicated that several of the reagents used were satisfactory as dust suppressing agents for the conditions under which the tests were made.

(4) Mechanical Dewatering of Dilute Suspensions

A general solution for the removal of free impurities (clay, sand and silt) from circulating washwater in a coal washery and from effluent in a coal reconstitution plant has been found.

A flowsheet consisting of the following steps has been developed:

1) Removal of fine coal particles from effluents by means of oil agglomeration, centrifuging and aeration;
2) Stripping of solids (sand) from remaining effluents with 2 in. classifying cyclones operating as slugging cyclones;
3) Removal of finely dispersed clay and silt in an inclined clarifier with the aid of flocculants;
4) Final purification of effluents in an upward current filter.

In the case of circulating washwater in a coal washery, where complete removal of fine solids from the water is not necessary, filtration and possibly clarification in an inclined settler will not be required, as water containing 500-1000 ppm solids can be kept in circulation.

When effluents have to be discharged in streams the very strict specifications for environmental control have to be met. The inclined clarifier is then necessary to produce water with 100 ppm solids, to enable the filter to further clean the effluent to 25 ppm solids or less.

Projected Costs and Scheduling

	Man Years per Year			Cost/	Total Cost
	72/73	73/74	74/75	Man Year	for 3 Years
Professionals	5	5	5	15,000	$225,000
Technicians	2	2	2	8,000	48,000
Overhead					30,000
Total					$303,000

Following are some projects of the Energy Activity dealing with some aspects of the Environmental Department Activity (the page no. refers to Energy Activity, Divisional Report, Metals Reduction and Energy Centre 71/63):

a) Gravimetric separation of coal, ore and industrial minerals: p. 8, (8) (b).
b) Effluent treatment and slimes disposal: p. 8, (8) (c).
c) Improvement of electric furnace efficiency: p. 27, (3) (a) and p. 30, (8) (a) (v).
d) Development of new processes for treating sulphide ores: p. 27, (3) (b) and p. 30, (8) (b).
e) Research in coal fines processing: p. 38.
f) Research on special control analytical methods: p. 44.

5. PHYSICAL METALLURGY DIVISION

Pollution Abatement in Melting and Casting

(1) Situation

The Canadian metallurgical industry is faced with increasing restriction in its operations through the application of various pollution control measures applied by different authorities from the municipal to the federal level. To satisy these new requirements entails additional operational and capital expenditures which, by increasing costs, make Canadian products less competitive in terms of world markets.

(2) Planning Assumptions

It is assumed that, because of increasing social conscience, and increasing political pressure brought to bear by the rapidly growing urban population, the demand for a "clean" environment and in particular "clean air" will increase in the urban centres where most of the secondary manufacturing plants are now located.

Besides this growing outside pressure, it appears that in the near future many plants will be faced with internal pressure in terms of union demands for cleaner environments and pollution control as part of contract settlements.

While the above applies to all Canadian industry, it applies particularly to melting and casting operations where high temperature, chemical treatment of molten metal, and breakdown of organic material in the mould often results in the copious evolution of fumes, smoke, and combustion products. These operations are estimated to have a product value of $1,500 million at the present time, and to be carried out in about 250 plants, ranging from integrated steel producers to small foundries.

In the face of this increased pressure for less or no effluent from such plants, it is assumed that these companies will continue to expect that, as in the past with other metallurgical difficulties, they can look to the Mines Branch for cheaper or better solutions to their problems.

(3) Relation to Other Mines Branch Studies

The project to be undertaken by the Physical Metallurgy Division forms part of an over-all program on pollution control which is centred in the Fuels, Extraction Metallurgy, Mineral Sciences and Physical Metallurgy Divisions. This program embraces the major aspects of combustion, smelting processes, and secondary manufacturing as applied to the metallurgical industry. This program will be coordinated through meetings of the Committee on Pollution Abatement.

(4) National Need

Apart from the large companies which have competent engineering and metallurgical staff, the industry is caught between increasingly stringent regulations for pollution control on the one hand and lack of experience and knowledge on the other. It would appear also that the regulations might not be uniform across the country so that solutions to a specific problem may well vary from one location to another. Thus, there is a need for some central body to assess the various factors involved and to propose both long- and short-term solutions which are economically and sociologically viable.

(5) Alternatives

In many cases, when faced with pollution control regulations, there are four alternative solutions:

a) Move to an area where control measures are less restrictive--which normally means moving to a less densely populated area, although this may not apply in the future.
b) Purchase control equipment on the advice of their own engineering staff or that of consultants or equipment suppliers.
c) Modify the process to avoid or reduce pollution to acceptable levels.
d) Close down the plant if the above alternatives are not feasible for economic or technological reasons.

Our project aims primarily at item c), although information may be generated which would be useful in b). Alternatives to carrying out the proposed work in the Mines Branch would be for industry to carry out the work in its own laboratories, to contract for the work at university or research institutes, or for government to do the same alone or in cooperation with industry.

The project chosen by the division is based on national need, expertise and equipment within the division for studies of this type, and industrial contacts already established through other work in similar fields.

(6) Criteria

Besides the considerations of appropriate staff and facilities, it is considered that without assistance most companies will attempt to solve the problem by purchasing pollution control equipment. While this is an accepted solution, it adds costs to manufacturing which might be avoided or reduced if the process itself could be modified so that the effluent was not generated in the first place, was reduced, or was changed in character or composition. Thus, the proposed program on process modification should help Canadian industry remain competitive in world markets.

(7) Preferred Courses of Action

It is suggested that for the long-term view, process modification as a means of controlling pollution offers the most economical solution, and that the work proposed offers good prospects of helping those sectors of the metallurgical industry, namely melting and casting, which are most immediately affected.

(8) Project Titles and Objectives

a) Reduction of Atmospheric Pollution in the Melt Treatment of Non-Ferrous Alloys

Noticeable pollution occurs from metallurgical operations on aluminum and copper alloys. Chlorination of aluminum alloys in their degassing, cleaning and magnesium removal results in pollution by gaseous chlorine and hydrogen chloride and by copious white fumes of aluminum chloride. The latter are particularly difficult to collect.

Emissions from the melting, casting and cleaning of copper alloys include combustion products such as fly ash, smoke and trace amounts of sulphur dioxide from fuels and contaminated materials. The presence in brass and bronze of low-boiling-point alloying constituents such as zinc and lead results in the collected dust containing 56 to 96 per cent zinc oxide and 6 to 8 per cent lead oxide.

Initial work has concentrated on improving the efficiency of chlorination of aluminum. In the magnesium stripping operation, it has been found that excess chlorine and aluminum chloride can be absorbed in a magnesium chloride based flux. This technique can hopefully be extended to eliminate all gaseous emissions from this operation. Alternative methods of cleaning and degassing aluminum alloys are being examined, such as using fluxes and oxidation techniques.

b) Removal of Particulate from Hot Gases

For a number of reasons including limitation of space and equipment, it was decided to replace the original concept involving Fumeless Refining of Steel, and Reduction of Particulate and Gaseous Pollutants from Cupolas with the project described below.

All pyrometallurgical operations emit varying amounts of gaseous and particulate matter. In general, pollution abatement is designed to handle relatively cool gases and, when used in a pyrometallurgical operation.

the first stage is generally involved with cooling the waste gases with water or by dilution with cool air. When water is used, corrosion is often a problem when dilution air is introduced; the volume of gas to be treated is increased, and equipment of greater capacity is required. The heat content of these gases is of course lost. Thus, a technique by which particulates could be removed without cooling of the gases would appear to be desirable.

A project has been devised that involves the use of a permeable bed of refractory material through which the particulate-laden gas would be passed. The size of the particle removed should be related to the grain size of the refractory bed (i.e., the permeability). Thus, a series of successively smaller grain size beds should remove successively finer particles. The efficiency of removal of particulates from a hot gas stream as well as the optimum pressure drop across each bed would have to be established. The possibility of mixing chemically active solids in the bed to react with certain gaseous compounds also exists in such a technique and requires investigation, e.g., limestone to remove sulphur dioxide.

Although this approach has potential applications in a wide variety of pyrometallurgical operations, it was felt that initially we would concentrate on its application to small cupolas and expand it to other areas if it were successful in this field.

The information available on the amount and composition of gaseous and particulate emissions from cupolas is sparse and of questionable validity. The design and operation of a cupola is such that uniform flow of gas in the stack cannot be expected and wide variations in gas velocity, temperature, composition and particulate content at a given level in the cupola stack should be anticipated. Thus, unless a great deal of care is taken and a large number of samples obtained, the data obtained from a sampling of cupola emissions would likely be in error.

A program has, consequently, been carried out in cooperation with the Ontario Department of Energy and Resources Management to accurately determine the amount, size, distribution and composition of the particular emission from selected cupolas, as well as the quantity and composition of the stack gases. With this information, we are now in a position to regulate our tests to more closely duplicate the type of particulate and gaseous emissions as well as gas temperatures, actually encountered in commercial operating cupolas.

(9) Projected Costs and Scheduling

	Man Years per Year			Cost/ Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	3	3	3	15,000	$135,000
Technicians	3	4	4	8,000	88,000
Plant, services and overhead					131,000
Total					$354,000

(10) Benefits

The benefits to be realized in the proposed program can be classed under headings

a) sociological—provision of a cleaner environment.
b) reduction in capital and operational costs in terms of the purchase, maintenance and operation of pollution control equipment.
c) possible development of new processes which have technical, economic or sociological advantage.
d) possible economic utilization of waste products (conservation).

In terms of a), it should be appreciated that, while the air pollution problem in the melting and casting industry is severe, particularly within the plant and to its immediate neighbours, this is only a relatively small part of the 20 per cent of air pollution which is attributed to industrial process (as opposed to the 60 per cent attributed to the transportation industry, for example). However, on the local scale, in a city like Hamilton, or in a small community faced with closure of their major employer--a foundry, for example, the problem of removing pollution from the effluent gas at minimum cost is of vital concern.

It should also be appreciated that the project will take some time to complete, whereas, particularly in Ontario, industry is being faced with demands for an immediate solution to the problem. Thus, some plants will be forced into the purchase of pollution control equipment whereas the optimum solution to the problem might well lie in process modification. In the long-term, however, it is anticipated that the project will provide data which will lead to the more efficient design and application of air cleaning equipment appropriate to specific metallurgical processes, and will develop new or modified processes leading to the generation of less, or less harmful effluents, again reducing or eliminating the cost of treatment.

As noted, these will be accompanied by the advantages of a cleaner environment within the plant and within the community.

(11) Estimated Input-Output

In view of the nature of the problem, the only economic advantages which can be realized are in terms of reduced expenditures rather than increased profits or productivity, and it is apparent that the cost of pollution control must be borne by the particular industry and/or the community at large through increased taxation or increased cost of manufactured products.

It is also difficult to estimate potential savings as it is not known to what extent there will be uniformity of regulation and enforcement within the provinces, or the time schedule over which regulations will be applied.

Against this background, it may be noted that three major Canadian steel producers are proposing to spend $96 million over the next six years on pollution control measures, so that a reduction of even say 2 per cent in this sector alone still represents considerable savings.

(12) References

Internal Report PM-I-70-5. Information Seminar on the Mines Branch Air Quality Research Program, January 8 and 9, 1970, Ottawa. "Highlights of Physical Metallurgy Submissions", edited by R. F. Knight, January 1970.

Internal Report PM-I-70-14. Second Seminar of the Mines Branch Committee on Environmental Improvement, November 17, 1970. "Fume Control in Refining Secondary Aluminum" by L. V. Whiting, November 1970.

SUB-ACTIVITY 3: REDUCTION OF POLLUTION IN MINES

OBJECTIVE

To reduce pollution and hazards in mines.

BACKGROUND AND SCOPE

The presence of explosive gases or vapours has long been recognized in coal mining and many other operations as an occupational hazard. Some gases such as carbon monoxide and hydrogen sulphide are both toxic and explosive. Only too frequently, there have been explosions in Canada, involving great loss of life and property. While safety in mining and other industries is a matter of provincial responsibility, the provinces themselves have favoured centralized establishments rather than a proliferation of provincial agencies to provide consultation concerning hazards and also certification services. It was due to a number of submissions to this Department, arising from Provincial Mines Ministers' Conferences, that the certification of coal mining electrical equipment was begun in 1955. Shortly thereafter, the Canadian Standards Association Testing Laboratories requested the assistance of the Canadian Explosive Atmospheres Laboratory for certification in Canada of electrical equipment for use in hazardous locations other than mining. Previously, they had relied on United States laboratories. Research in the explosive atmospheres field of phenomena associated with ignition, sources, explosion propagation, transmission of flames through joints and channels, is necessary to carry out the objectives in a competent manner. Very shortly after starting operations requests were received for assistance in determining the causes of a number of disastrous explosions in Canada involving considerable loss of life. Also, after requests were received, the Director authorized the head of the laboratory to assist in committee work to establish national standards and international recommendations, which, incidentally, have a bearing on imports, exports, and international acceptance of electrical products. Government departments and other organizations (including the Department of National Defence and the Atomic Energy of Canada) have sought advice to help prevent explosions. In the light of the above, the scope of research enlarged to include studies of specialized problems. Certification services have included studies of diesel engine exhaust toxicity and pollution of mine air, as well as the explosion hazard from diesel engines. Also, the fire and explosion hazard from combustible conveyor belting on electric-motor-driven conveyors has led to certification of fire-resistant conveyor belting.

Sub-Sub-Activity 1: Research on Explosive Gases on Ignition and Explosion Phenomena

OBJECTIVE

To increase the understanding of ignition and explosion phenomena, improve safety codes and construction specification and provide a broad background of information useful for the solution of special problems.

(1) Situation

In Canada, explosions have occurred all too frequently in mines, hospitals, buildings, factories, etc. These have produced a heavy toll in lives and property damage.

(2) Planning Assumptions

Continuous research in the explosive atmosphere field provides the basic information required as a foundation on which to base national specifications and international recommendations for electrical apparatus for hazardous locations. These, in turn, affect the acceptability of Canadian products in world markets. Also, the work, in large measure, provides the competence and expertise required for efficient consultation services with regard to the solution of Canadian problems associated with explosion hazards. In papers presented at conferences, such as the International Conference of Directors of Safety in Mines Research, Canada contributes to efforts which increase safety in mining operations throughout the world.

A few of the numerous problems, which have been studied in the laboratory are, as follows:

(a) Transmission of methane-air explosions through cylindrical channels.
(b) Determination of maximum experimental safe gaps in explosion-proof enclosure joints for hydrogen explosion hazards.
(c) An ignition hazard of aluminum explosion-proof enclosures, due to inflammation of aluminum particles.
(d) Variations in explosion pressures with the internal surface to volume ratio of explosion-proof enclosures.
(e) Extent of hazardous areas, associated with leakage during normal administration of flammable anaesthetics in hospital operating rooms.
(f) Incendivity of sparks from iron-cored inductance circuits.
(g) Diffusion of gases through joints in enclosures.

Over a hundred problems, such as those above, have been the subject of our research. It is assumed that the requirement for specific information in the subject areas outlined above will continue at an accelerated pace in view of the demand for mining equipment for the production of coking coal for the Japanese market and the steady growth of the Canadian electrical industry, which is becoming more conscious of the developing possibilities in the export market of specialized equipment.

(3) Relation to Other Mines Branch Activities

Advice is given on electrical equipment for use in hazardous areas of hydrocarbon processing where both hydrocarbon vapours and hydrogen are present.

(4) National Need

The Canadian Explosive Atmospheres Laboratory is a unique facility serving both the mining and the electrical industries. The ability to give sound advice to manufacturers and standardization bodies, such as the Canadian Standards Association, depends on the availability of a fund of knowledge based on continuing research on ignition and combustion phenomena. As both the ignition and the propagation of combustion depend upon the geometrical properties of the equipment as well as the materials of construction and the type of combustible gas, continual investigation must be undertaken to study the behaviour of the innumerable special cases, and to attempt to generalize the results where possible.

(5) Alternatives

The alternatives would appear to be either to conduct research to support the certification function of the Canadian Explosive Atmospheres Laboratory or not. If no research were conducted, the certification service would ultimately deteriorate into an office applying standards worked out in other countries. This is not what the Ministers of Mines of the Provinces had in mind when they approached the Federal Government to establish this service.

(6) Criteria

The criteria used to select projects are basically judgements based on engineering experience and knowledge of the field. An assessment is made of the most important aspects of combustion, ignition or transmission through gaps that require study to support the certification function. Considerable effort has been spent on the study of the transmission of ignition through gaps, using hydrogen-air mixtures, as this is an area of growing technical importance in oil refining and petrochemical processing. The Canadian Explosive Atmospheres Laboratory is the only laboratory in Canada where systematic research can be done in this field, as the investment in personnel and instrumentation is greater than the provinces or industry can sustain individually. For this reason, the Ministers of Mines of the Provinces recommended that a central service be supplied by the Federal Government.

(7) Preferred Courses of Action

It is desirable to select research projects in such a manner that the results will be capable of the widest possible generalization, and have the greatest technical significance. In the past, this has meant that the relationship between the rate of pressure-rise, the maximum pressure, and the surface-to-volume ratio have been studied. In the future, studies will be made of the energy requirements to cause ignition.

(8) Project Titles and Technical Objectives

A number of project-research titles were given for the field of explosive gases in item (2). It was mentioned that over a hundred such projects had been the subject of research. As an example, one of the projects of particular interest is the following:

Title: Laboratory Investigations of Hydrogen Explosion Phenomena Relating to Electrical Apparatus

Technical Objectives: The relative ease of ignition of mixtures of hydrogen and air throughout the flammable range by electric spark was found, and compared to the ignition of pentane and air mixtures. A determination was made of the relationship of percentage by volume of hydrogen in air to explosion-pressure in a small cubical enclosure (one-quarter of a cubic foot in volume); and also of the time to reach peak pressure in the same enclosure. A study was made of the transmission of hydrogen explosions through flat joints by means of apparatus, which permitted variation of the gap size, the joint width, and the free volume. As the apparatus for this study was such that the gap could not expand due to explosion pressure, a further study was made of explosion transmission through the shimmed flat joints of several commercial-type, explosion-proof enclosures and an experimental enclosure: all of which had bolted covers, and for which the gap changed due to pressure during an explosion. Experiments were also conducted on diffusion of hydrogen into enclosures, and the possibility of transmitting hydrogen explosions through threaded joints. The results of the various studies were presented, discussed, and, in some cases, related to theoretical equations or otherwise interpreted. A major objective of this study was to provide a logical basis for specifications, which were to be established for the construction of electrical apparatus for use in hydrogen-hazardous locations.

When the above was completed, there still remained many unexplained aspects of the same problem, and laboratory investigations are still continuing.

Many of the projects referred to in item (2), like the one described above, are investigated on a continuing basis.

(9) Projected Costs and Scheduling

	Man Years per Year			Cost/ Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	1	1	1	15,000	$ 45,000
Technicians	2	2	2	8,000	48,000
					$ 93,000
Plant, service and overhead					87,000
					$180,000

(10) Benefits

The benefits that are derived from this type of work are the stimulation of the domestic electrical industry to produce modern electrical equipment for the mining, petroleum and the chemical industries where hazardous atmospheres exist. It also opens the way for Canadian electrical equipment to enter the export market by making available new data upon which designs may be based.

(11) Input/Output Estimates

N/A

(12) References

1. Determination of the Most Readily Ignitable Mixture of Hydrogen with Air.

2. Tests Pertaining to Areas of Flammable Mixtures in Anaesthetizing Locations.

3. Tests of the Possibility of Ignition of Ether-Air Mixtures by the Melting of Small Fuse Wires.

4. The Ignitability of Explosive Atmospheres by the Heating Effect of Current Through Various Lengths and Diameters of Copper Wires.

5. Investigation of Pressure Development by Pentane-Air Explosions in Short Conduit Lengths.

6. Experimental Determination of the Relationship of Percentage of Hydrogen in Air (By Volume) to Explosion Pressure and Time to Reach Peak Pressure.

7. Theoretical Calculation of the Adiabatic Temperature, Pressure and Product Components of a Stoichiometric Hydrogen-Oxygen Explosion.

8. Analysis of the Energy Developed by the Electric Make and Break of the Fast Break-Flash Apparatus.

9. A Graphical Aid to Determine the Internal Gas Pressure of an Enclosure which Causes Bolt Failure.

10. Laminar Burning Velocity Variation with Tube Diameter.

11. Electrical Enclosure Stress Analysis Consideration.

12. Illustration of the Relationship of Burning Velocity and Flame Speed in an Enclosed Vessel.

13. Examination of the Entrainment Rate Equation for Hot Gas Transmission of Explosions Through Channels.

14. Ignition of Pentane-Air Mixtures by Fusing Small Diameter Copper Conductors in a Circuit of Low Inductance.

15. An Investigation of Explosion Transmission Through Short Cylindrical Channels of Varying Length and Diameter.

16. Hydrogen-Air Explosion Transmission Through Shimmed Gap in Flat Joints of Explosion Enclosures.

17. An Oscilloscope Study of Energy in Spark Produced by a Break-Spark Apparatus with Reference to Intrinsic Safety.

18. Laboratory Investigations of Hydrogen Explosion Phenomena Relating to Electrical Apparatus.

19. Internal Concentration Gradients Due to Diffusion of an External Methane-Air Mixture Through a Gap into a Cylindrical Volume.

20. The Non-Ignition of Acetylene Mixture Jets in a System Having Temperatures in Excess of Published Self-Ignition Temperatures.

21. Conflagration Characteristics of Pentane-Air Explosions in Cylindrical Enclosures.

22. The Determination by Calculation of the Variation of Safe Gap with Humidity Changes for Stoichiometric Hydrogen-Air Mixtures.

23. A Strain Investigation Performed on the Lid of a Cast Aluminum Explosion-Proof Enclosure.

24. An Explosion Hazard Due to Inflammation of Aluminum Particles in Flat Flanges of Flameproof Enclosures.

25. Heat Generation and Absorption of Flameproof Enclosures.

Sub-Sub-Activity 2: Certification of Electrical Apparatus

OBJECTIVE

To ensure the safe use of electrical apparatus used in locations where there is an explosion hazard, as in coal mines, and to evaluate the safety of prototypes of apparatus in relation to the development of equipment for oil fields or other industrial hazardous atmospheres.

(1) Situation

Prior to 1955 it was not possible to have electrical apparatus certified in Canada for use in gassy coal mines. Consequently, Canadian manufacturers were not interested in producing such apparatus, since--according to provincial regulations--it had to be certified and this could only be done in foreign countries. Further, CSA Testing Laboratories were not prepared to establish explosion-testing facilities.

At the time of establishment of the activity by this Department, a scale of fees was established by the Privy Council. Manufacturers in Canada have availed themselves, at a steadily increasing rate, of the certification service. CSA has also availed themselves of our explosion-testing facilities.

There are at least a half-dozen methods of making electrical apparatus safe in explosive atmospheres. The principles of these various methods are usually quite different. For example, intrinsic safety depends on the available energy in the electric circuits being too low to produce an incendive spark. On the other hand, an explosion-proof enclosure is expected to contain an explosion if it occurs inside the enclosure, and prevent it from being transmitted through joints to a surrounding explosive atmosphere. Other apparatus may be immersed in oil, or continually purged with fresh air, etc. All methods must only be done in a manner which meets specifications.

The scope of the service extends over the following areas:

(a) Certification of electrical apparatus for coal mines.
(b) Certification of safety lamps for tankers.
(c) Certification of apparatus for naval vessels.

(d) Certification of fire-resistant conveyor belting (there is an explosion hazard if belts on electrically-driven conveyors catch fire).
(e) Investigation, for development purposes, of apparatus for hazardous location in the oil industry.
(f) Investigation of the performance and safety of gas detectors.
(g) Explosion-testing on behalf of CSA Testing Laboratories of prototypes of a wide range of electrical apparatus.

(2) Planning Assumptions

In the equipping of the laboratory for certification work, the essential equipment for analysing explosive mixtures and explosion-testing enclosures and intrinsically-safe circuits was first acquired. Gradually, other equipment was added, such as that for testing motor starters under load, and for performing hydrostatic over-pressure tests on enclosures. As a result of inquiries from CSA, consideration was given to establishing a laboratory for the testing of circuit breakers at their rated interrupting capacity in explosive mixtures. A detailed investigation of this was made, and, as a result, space was provided in the explosive atmospheres building. However, the equipment would be in the order of 150 to 200 thousand dollars, and additional staff of an electrical engineer and a technician would be required. Since there is judged to be a more urgent national need for a diesel-exhaust-control laboratory, it is suggested that the equipping of the circuit-breaker-testing facility be deferred until after the diesel laboratory, described hereafter, is operational.

(3) Relation to Other Mines Branch Activities

The role played by the certification activity is somewhat analogous to that of the Explosives Division, which approves "permitted explosives" for use in gassy mines. There is no direct relation between the certification activity and other Mines Branch studies in the sense of providing service to other areas in the Branch.

(4) National Need

The submissions to the Department of Energy, Mines and Resources, arising from the Provincial Mines Ministers Conferences, are strong evidence of the national need. The steady increase in revenue taken in by this service since its commencement in 1955, is also evidence of the growing requirement for this type of service. The growing market for Western Canadian coking coal is expected to place some heavy demands on this service beginning in 1971. This expectation is based on the fact that approval will be required for the mining equipment for use in new underground mining.

(5) Alternatives

There is no other agency in Canada that is in a position to accept the certification responsibility, or that has the technical experts and equipment to carry out this function. The responsibility rests with the Federal Government to see that this function is operated at an efficient level, particularly as provincial mining legislation requires that all electrical equipment (a considerable amount) for use in gassy mines be certified before it is permitted to be used.

(6) Criteria

One criterion for judging the value of the Federal certification service is the steady increase in the revenue earned by this service. This has doubled approximately every five years, since its inception. In spite of the growth in the demand for this service, it has not been possible to support it with adequate technician help within the Mines Branch budget. This activity has had to be assisted by funds from the Dominion Coal Board to take care of the growth.

(7) Preferred Courses of Action

The preferred course of action is to keep pace with the growing demands of the mining industry, and avoid becoming a regulatory bottleneck. This means that the research activities supporting this function be maintained at a high level of efficiency. Some means have to be found to acquire staff consistent with the incoming load of work, as well as its diversity. With the present staff, it is only possible to maintain an efficient electrical certification service. Furthermore, because the Diesel Certification facilities are in the process of completion, it is necessary that adequate additional staff and operating funds be made available for this activity.

(8) Project Titles and Technical Objectives

The project titles correspond to specific equipment sent for certification, coming within the scope outlined for this activity under (1). The technical objective is to determine whether the equipment concerned meets the standards required for certification.

(9) Projected Costs and Scheduling

The equipment sent for certification arrives with little or no warning; scheduling is therefore difficult. Growing lists of companies waiting for their equipment to be approved is a matter of concern. The problem of building up reserves of capital to improve the facilities and increase the staff to reduce the waiting list should be given serious consideration.

	Man Years per Year 72/73	 73/74	 74/75	Cost/ Man Year	Total Cost for 3 Years
Professionals	2	2	2	15,000	$ 90,000
Technicians	1	1	1	8,000	24,000
					$114,000
Plant, service and overhead					66,000
					$180,000

(10) Benefits

The capital involved in underground mines in Canada where explosive gases exist, is a large sum involving millions of dollars. Improving the safety of operating such mines, thus reducing the risk of loss of life and property damage, is a very significant item. World-wide experience has shown that the detailed study of the performance of electrical equipment for use in mines to determine whether it is capable of withstanding an internal explosion without transmitting it to the surrounding atmosphere of explosive gas is very worthwhile.

The stimulation of the Canadian electrical industry to enter the export market is in its infancy, and therefore the benefits are difficult to evaluate. Nevertheless, it can be stated that developments are taking place in this area.

(11) Input/Output Estimates

N/A

(12) References

1. "Unitair" Air Compressor - Check on Its Flameproof Qualities.
2. Certification of MSA Minespot Electric Cap Lamp, Model ML-2.
3. Tests for Flame-Resistant Properties Conducted on Three Cables Spliced with "Thermofit Mines Cable Permanent Splice Kit".
4. Investigation of a Baldwin SR-4 Type N Portable Strain Indicator as Intrinsically Safe for Use in Coal Mines.
5. Investigation of Anti-Static Qualities of Conveyor Belts.
6. Explosion Tests Concerning the Model 2A Resistivity Field Unit.
7. Load Cell Bridge, Model 2A, Coal Mine Safety Investigation.

8. Certification of the 3 CML 100 "Borecut" Continuous Mining and Loading Machine.

9. Certification of the "Dosco Miner".

10. Certification of Vibrating Wire Strain Gauge Comparator Unit.

11. Investigation No. 285: Intrinsic Safety Study of Sony Cassette-Corder TC-100 Tapecorder.

Sub-Sub-Activity 3: Certification of Diesel-Powered Mining Equipment

OBJECTIVE

To ensure the control of exhaust emissions from diesel-powered mining equipment and safety with regard to explosion hazards.

(1) Situation

The use of diesel-powered apparatus in mines presents a problem of pollution of the mine air. If the mine is a coal mine, then the risk of explosion is also involved. It is known that many diesel engines are operating underground in Canada, and yet no laboratory other than our own is known to be concerned with investigating levels of emission of toxic gases in diesel exhaust for certification purposes. As in the case of electrical apparatus, the regulations in coal mining provinces require certification by an acceptable authority of diesel-powered equipment used underground. The Explosive Atmospheres Laboratory has been requested to provide such certification from time to time.

At the present time, the two most prevalent man-made sources of pollution underground arise from the use of explosives and diesel engines. The explosive fumes per pound of explosive are regulated, but the quality of the diesel engines is not. In the past, the main concern associated with diesel-engine operation underground has been the production of carbon monoxide. Presently, however, it is generally the presence of the oxides of nitrogen which dictates the fresh air ventilation requirements.

(2) Planning Assumptions

It had been assumed that underground diesel haulage will increase substantially in the next decade. Consequently, plans were made to build up the testing facilities so that manufacturers could be encouraged to improve the quality of diesel-engine performance. The facilities to investigate diesel equipment have virtually been completed and it is estimated that complete diesel investigations including engine performance investigations will be undertaken beginning October 1971. However, a technologist specializing in the mechanical aspects of the laboratory has yet to be assigned to help operate this facility.

(3) Relation to Other Mines Branch Activities

The diesel-testing facility is related to the program on atmospheric pollution as the larger part of the urban atmospheric pollution comes from gasoline and diesel engines. The new Department of the Environment has or is acquiring facilities to check automative exhaust, but they do not intend to service trucks or other heavy equipment. They stated that the FRC facility, if available, could serve to do such investigations. Many of the analytical services necessary in atmospheric-pollution studies would be supplied by the petroleum and natural gas analysis laboratory.

(4) National Need

At this stage in the growth of the use of diesel power in the mining and transportation industry, it is considered to be important to have one national centre where such engines can be tested and their pollution characteristics evaluated in terms of the load and speed of the engine. This has been recognized by manufacturers and mining associations alike. As a result a mini-conference is being held at the Corkstown laboratory during July, 1971, at the joint request of the Deutz Diesel Company and the Ontario Mining Association, to attempt to rationalize ventilation requirements based on engine exhaust analysis and to standardize provincial requirements to allow suitable equipment to be acceptable anywhere in Canada. Already three diesel machines have been certified for use in western coal mines supplying the Japanese market.

(5) Alternatives

No other agency at the present time, in Canada, is in a position to offer this type of service or to provide the required associated multidisciplinary experience.

(6) Criteria

Part of the need for this service has been judged on the basis of the number of inquiries to have diesel equipment certified. Another important factor is consideration for the health and safety of the miners.

(7) Preferred Course of Action

The preferred course of action would be to acquire a mechanical technologist for full time concern with all of the mechanical assembly and repair requirements of the diesel-testing facility, then to pursue the main laboratory objective of certification of mining machinery, but in addition to explore further research avenues available to us, such as, the improvement of exhaust-end purification systems with the help of this division's Catalysis Section.

(8) Project Titles and Technical Objectives

(a) Familiarization and Run-up Investigations to place the Diesel Facility into full operation.
(b) Certification of Diesel Machines for Coal and Non-Coal Mines.
(c) Detailed Examination of the stability, life, toxic effects and concentrations of the several oxides of nitrogen present in IC engine exhaust, to establish procedures for analysis.
(d) Completion of some additions necessary for the handling of gasoline engines and the monitoring of exhaust hydrocarbon content.
(e) The preparation (if deemed advisable--a provincial mining authority has already made suggestions) of a Canadian Federal Diesel Testing Standard for Mines (Coal and Non-Coal).
(f) Transport Vehicle and other heavy equipment engine investigations to determine the concentration of atmospheric air polluting constituents.
(g) Cooperation with university research programs where possible (University of Toronto has already indicated such as interest, and Carleton University has a research program presently underway, as does Ottawa University), and with other sections such as the Catalysis Section for researching exhaust purification systems.
(h) During June 1971, an interest was expressed by mining officials of the three Prairie Provinces in determining, by research in the CEAL Facility, the following items of information:

    1. the efficiency, qualitative and quantitative of a venturi entrainment system to dilute diesel exhaust before emission from a vehicle.
    2. substantiation for provincial authorities of the various cartridge type (on site) toxic constituent analysers, using this laboratory's infra-red equipment as comparison standards.
    3. a determination of the relative safe ventilation between haulage ways (where mixing is good), and ore faces (where mixing is not as good), with a view to compensating for wide seasonal variations in ambient air temperatures, a condition peculiar to Canada, or alternatively, rating a Diesel machine on the basis of maximum rate of toxic contaminants generated and letting provincial authorities determine ventilation rates appropriate to local conditions.

4. the relative performance of a Diesel-electric mining machine compared to an equivalent direct-drive Diesel machine from the standpoint of total toxic emissions.
5. the assessment of hydraulic system fluids for the purpose of reducing fire hazards.
6. the establishment of safe wiring protection standards for diesel machinery operating in non-coal, non-gassy mines.

(i) At present the available standards of other nations do not define detailed requirements for safe braking systems from the standpoint of heat and spark generation in gassy mines.

(9) Projected Costs and Scheduling

It is expected that item 8(a) will be completed in October 1971, and that 8(b) will begin in earnest at that time. Aside from salaries it is estimated that a further $3000 of capital equipment and tools will be required to complete and operate the facility until the end of the fiscal year in April 1972. The balance of the projects would not begin until the following fiscal year.

	Man Years per Year			Cost/ Man Year	Total Cost for 3 Years
	72/73	73/74	74/75		
Professionals	4	5	5	15,000	$210,000
Technicians	2	3	3	8,000	64,000
					$274,000
Plant, service and overhead					166,000
					$440,000

(10) Benefits

The benefits are: (1) improved conditions of safety and health in the underground mining activities in Canada, (2) substantial savings to mining companies operating in several provinces resulting from a more ready transfer of federally certified equipment between provinces, (3) more rapid utilization of newly acquired equipment by mining companies if federal certification has been acquired prior to purchase, (4) the opportunity to purchase the most economical diesel equipment in a world market, (5) the potential to develop a national diesel mining equipment industry, because uniform certification standards would make the entire Canadian market available to a fabricator with no modifications to a particular design. Development assistance could be provided to such fabricators by the Certification Agency, as is done in other countries, (6) improved ambient air conditions in the urban environment should the facility be used for assisting the environmental regulating authorities.

(11) Input/Output Estimate

N/A

ENVIRONMENTAL IMPROVEMENT ACTIVITY: 3-YEAR FORECAST

SUB-ACTIVITY AND SUB-SUB-ACTIVITY	PTO	Man Years			Cost/ Man Year	Total 3 Years
		72/73	73/74	74/75		
Characterization of Pollutants and Development of Pollution-Free Processes and Dispersion and Disposal of Effluents						
1. Canadian Combustion Research Laboratory						
Characterizing of Pollutants	P	2	2	2	15,000	$ 90,000
	T	1	1	1	8,000	24,000
	O					114,000
						$228,000
Blue Flame	P	1	1	1	15,000	$ 45,000
	T	0.5	0.5	0.5	8,000	12,000
	O					45,000
						$102,000
Combustion Process Phenomena	P	2	2	2	15,000	$ 90,000
	T	1	1	1	8,000	24,000
	O					114,000
						$228,000
Incineration	P	1	1	1	15,000	$ 45,000
	T	0.5	0.5	0.5	8,000	12,000
	O					30,000
						$ 87,000
Plume Dispersion	P	1	1	1	15,000	$ 45,000
	T	1	1	1	8,000	24,000
	O					81,000
						$150,000
Field Evaluation	P	1	1	1	15,000	$ 45,000
	T	1	1	1	8,000	24,000
	O					15,000
						$ 84,000
Total, Combustion Research Laboratory		13	13	13		$879,000

P = Professional T = Technician O = Overhead including equipment and supplies

SUB-ACTIVITY AND SUB-SUB-ACTIVITY	PTO	Man Years			Cost/ Man Year	Total 3 Years
		72/73	73/74	74/75		
2. Extraction Metallurgy Division						
Minimizing Gaseous Pollution	P	2	2	2	15,000	$ 90,000
	T	2.5	2.5	2.5	8,000	60,000
	O					74,000
						$224,000
Minimizing Aqueous Pollutants	P	3	3	3	15,000	$135,000
	T	1	2	2	8,000	40,000
	O					80,000
						$255,000
Support Services	P	0.85	0.85	0.85	15,000	$ 38,250
	T	4.3	4.3	4.3	8,000	103,200
	O					137,550
						$279,000
Total, Extraction Metallurgy Division		13.65	14.65	14.65		$758,000
3. Mineral Sciences Division						
Characterization of Pollutants and Development of Pollution-Free Processes	P	1.5	1.5	1.5	15,000	$ 67,500
	T	0.6	0.6	0.6	8,000	14,400
	O					83,100
						$155,000
Dispersion and Disposal of Effluents	P	2	2	1	15,000	$ 90,000
	T	1	1	1	8,000	24,000
	O					116,000
						$230,000
Total, Mineral Sciences Division						$385,000
4. Metals Reduction and Energy Centre						
Pollution from Electric Smelting, Lead Smelting, and Coal Transportation	P	5	5	5	15,000	$225,000
	T	2	2	2	8,000	48,000
	O					30,000
						$303,000
Total, Metals Reduction and Energy Centre						$303,000

SUB-ACTIVITY AND SUB-SUB-ACTIVITY	PTO	Man Years 72/73	73/74	74/75	Cost/ Man Year	Total 3 Years
5. Physical Metallurgy Division						
Melting and Casting	P T O	3 3	3 4	3 4	15,000 8,000	$ 135,000 88,000 131,000 $ 354,000
Total, Physical Metallurgy Division						$ 354,000
Reduction of Pollutants in Mines						
Research on Explosives Gases	P T O	1 2	1 2	1 2	15,000 8,000	$ 45,000 48,000 87,000 $ 180,000
Certification of Electrical Apparatus	P T O	2 1	2 1	2 1	15,000 8,000	$ 90,000 24,000 66,000 $ 180,000
Certification of Diesel-Powered Mining Equipment	P T O	4 2	5 3	5 3	15,000 8,000	$ 210,000 64,000 166,000 $ 440,000
Total, Reduction of Pollutants in Mines						$ 800,000
Total, Environmental Improvement Activity						$3,479,000

5. SUMMARY OF MINES BRANCH ACTIVITIES: 3-YEAR FORECAST 1972/75

Activity	Professional and Technical Man-Years			Total 3 Years
	1972/73	1973/74	1974/75	
1. Mining	57.5	57.0	58.0	3,739,600
2. Minerals and Metals				
(1) Mineral Processing	73.0	77.0	80.5	4,125,750
(2) Extraction Metallurgy	40.3	40.3	40.3	2,267,000
(3) Physical Metallurgy	109.0	110.0	110.0	5,990,600
(4) Mineral Sciences	79.0	79.0	79.0	3,469,500
Sub-total: Minerals and Metals	301.3	306.3	309.8	15,852,850
3. Energy				
(1) Fuels Research	55.0	70.0	70.0	4,200,000
(2) Metals Reduction and Energy	47.0	49.0	49.0	2,282,000
(3) Extraction Metallurgy	9.4	9.4	9.4	646,500
(4) Physical Metallurgy	12.0	12.0	12.0	647,100
Sub-total: Energy	123.4	140.4	140.4	7,775,600
4. Environmental Improvement				
(1) Canadian Combustion Research Lab.	13.0	13.0	13.0	879,000
(2) Extraction Metallurgy	13.7	14.7	14.7	758,000
(3) Mineral Sciences	5.1	5.1	5.1	385,000
(4) Metals Reduction and Energy	7.0	7.0	7.0	303,000
(5) Physical Metallurgy	6.0	7.0	7.0	354,000
(6) Mining	12.0	14.0	14.0	800,000
Sub-total: Environmental Improvement	56.8	60.8	60.8	3,479,000
TOTAL ACTIVITIES	539.0	564.5	569.0	30,847,050

Note that the above total does not include the Office of the Director (administration, planning, financial services, library, information services, grants, etc.) nor the Technical Services Division.